MAY 1 1919
UNIV. OF MICH.

Notice to Reader.—When you finish reading this magazine, place a 1 cent stamp on this notice, mail the magazine, and it will be placed in the hands of our soldiers or sailors
No wrapping—No Address.

Vol. 8, No. 5 MAY, 1919

THE SCIENTIFIC MONTHLY

CONTENTS

BIOMETRIC STANDARDS FOR ENERGY REQUIREMENTS IN HUMAN NUTRITION. Dr. J. Arthur Harris and Dr. Francis G. Benedict 385

AN ENTOMOLOGICAL CROSS-SECTION OF THE UNITED STATES. Professor J. Chester Bradley 403

PSYCHO-PHYSICAL TESTS OF AVIATORS. Professor George M. Stratton 421

DELUSION, MASS-SUGGESTION AND THE WAR: A DREAM AND THE AWAKENING. Professor Joseph Jastrow 427

TROPICAL VERSUS ARCTIC EXPLORATION. The Late Theodoor de Booy . 433

THE OLD INTERNATIONALISM AND THE NEW LEAGUE OF NATIONS. Dr. C. C. Eckhardt 437

THE PSYCHOLOGY OF DEMOCRACY IN PUBLIC EDUCATION. Professor David Spence Hill 442

NERVOUS AND OTHER FORMS OF PROTOPLASMIC TRANSMISSION. Professor Ralph S. Lillie 456

THE PROGRESS OF SCIENCE:
Education for American Soldiers in France; The American Museum of Natural History; Exploration in the American Arctic Regions; Scientific Items 475

THE SCIENCE PRESS

LANCASTER, PA. GARRISON, N. Y.

NEW YORK: Sub-Station 84

Single Number, 30 Cents Yearly Subscription, $3.00

Copyright 1917 by The Science Press

A Remarkable Textbook

Barber's First Course in General Science

By FREDERICK D. BARBER, Professor of Physics in the Illinois State Normal University, MERTON L. FULLER, Lecturer on Meteorology in the Bradley Polytechnic Institute, JOHN L. PRICER, Professor of Biology in the Illinois State Normal University, and HOWARD W. ADAMS, Professor of Chemistry in the same. vii+588 pp. of text. 12mo. $1.25.

A recent notable endorsement of this book occurred in Minneapolis. A Committee on General Science, representing each High School in the city, was asked to outline a course in Science for first year High School. After making the outline they considered the textbook situation. In this regard, the Committee reports as follows:

"We feel that, in Science, a book for first year High School use should be simple in language, should begin without presupposing too much knowledge on the part of the student, should have an abundance of good pictures and plen[illegible] of material to choose from.

Barber's *First Course in General Science* seems to us to best meet these requirements and in addition it suggests materials for home experiments requiring no unusual apparatus, and requires no scientific measurements during the course. We recommend its adoption."

Other Interesting Opinions on the Book Follow:

SCHOOL SCIENCE AND MATHEMATICS:—It is one of the very best books on general science that have ever been published. The biological as well as the physical side of the subject is treated with great fairness. There is more material in the text than can be well used in one year's work on the subject. This is, however, a good fault, as it gives the instructor a wide range of subjects. The book is written in a style which will at once command not only the attention of the teacher, but that of the pupil as well. It is interesting from cover to cover. Many new and ingenious features are presented. The drawings and halftones have been selected for the purpose of illustrating points in the text, as well as for the purpose of attracting the pupil and holding his attention. There are 375 of these illustrations. There is no end to the good things which might be said concerning this volume, and the advice of the writer to any school board about to adopt a text in general science is to become thoroughly familiar with this book before making a final decision.

WALTER BARR, *Keokuk, Iowa*:—Today when I showed Barber's Science to the manager and department heads of the Mississippi River Power Co., including probably the best engineers of America possible to assemble accidentally as a group, the exclamation around the table was: "If we only could have had a book like this when we were in school." Something similar in my own mind caused me to determine to give the book to my own son altho he is in only the eighth grade.

G. M. WILSON, *Iowa State College*:—I have not been particularly favorable to the general science idea, but I am satisfied now that this was due to the kind of texts which came to my attention and the way it happened to be handled in places where I had knowledge of its teaching. I am satisfied that Professor Barber, in this volume, has the work started on the right idea. It is meant to be useful, practical material closely connected with explanation of every day affairs. It seems to me an unusual contribution along this line. It will mean, of course, that others will follow, and that we may hope to have general science work put on such a practical basis that it will win a permanent place in the schools.

Henry Holt and Company

NEW YORK BOSTON CHICAGO

THE SCIENTIFIC MONTHLY

MAY, 1919

BIOMETRIC STANDARDS FOR ENERGY REQUIREMENTS IN HUMAN NUTRITION

By Dr. J. ARTHUR HARRIS and Dr. FRANCIS G. BENEDICT

CARNEGIE INSTITUTION OF WASHINGTON

ONE of the primary requisites in all of the exact sciences is the establishment of standard bases of comparison. For a decade the Nutrition Laboratory of the Carnegie Institution of Washington has been engaged in the precise investigations which must underlie the establishment of such standards in human nutrition.

This is an undertaking of the greatest practical importance. In times of peace, industrial efficiency and the physical well-being of the population demand exact knowledge of the amount and proportion of the different kinds of food which should be taken by the individual. If communities or nations are to be stringently rationed during periods of emergency, it is also necessary to know the minimum amounts of food required to maintain health and efficiency.

The problem is also one of great complexity. Aside from all questions concerning the chemical composition, digestibility and other physiological properties of the various foods, there are a large number of problems concerning the characteristics of human individuals which must be taken into account.

For example, it is obvious that those who are engaged in severe muscular work must consume larger quantities of food supplying energy than those who are less active. It might seem reasonable to suppose that larger individuals would require more food to carry on their normal activities than those who are physically smaller. It is a matter of common observation that older men and women demand smaller rations than those in the earlier stages of life.

All these questions require precise investigation before one is justified in drawing conclusions concerning them. If such investigations are to be used as a basis of recommendation concerning diet in peace or of regulation of diet in war, it is essential that the laws of energy transformation be expressed in a quantitative form.

Nutritional physiologists agree that, as far as energy is concerned, the food requirements of the living organism shall be expressed in calories per unit of time. Thus a physical standard is taken over from the quantitative sciences of physics and chemistry. Theoretically, then, the metabolism must be determined by placing the subject in a calorimeter and directly measuring the number of calories produced. This has been done in a large number of cases.

Since, however, the setting free of energy in the human body is merely a process of combustion, the measurement of the amount of oxygen consumed and the quantity of carbon dioxide excreted from the lungs should furnish a good index of heat production. Thus the nutritional physiologist may avail himself of the method of *indirect calorimetry* as well as of *direct calorimetry*. Heat production, in short, may be determined in a calorimeter or it may be computed from the gaseous exchange as measured in a respiration chamber.

The development of apparatus by which the heat production of the living organism may be directly measured in the calorimeter or by which the gaseous exchange may be precisely determined in the respiration chamber has occupied the attention of a large number of ingenious experimenters, among whom may be mentioned Lavoisier, Rubner, Zuntz, Atwater, Rosa, Lusk and Du Bois. The labors of these and others have brought the apparatus for the measurement of both heat production and gaseous exchange to such a high degree of refinement that the manipulative phases of nutritional physiology may be regarded as among the most exact techniques of biological experimentation. Extensive comparative studies have shown that, in the case of human subjects, it is much simpler and essentially as accurate to calculate the heat production indirectly from the gaseous exchange than to measure it in the calorimeter.

The problem is not, however, solely one of physical and chemical measurement. A number of biological factors must be taken into account. Muscular activity and the stimulatory action of recently ingested food are of chief importance. The apparatus with which students of human nutrition now work

has been brought to such a stage of perfection as to measure the energy transformation accompanying such slight muscular activity as that required in the raising of the hand from the side to the mouth. The cost in calories of masticating food may be directly measured. For example, recent studies at the Nutrition Laboratory by Carpenter and Benedict have shown that the muscular work in chewing gum may increase heat production approximately 17 per cent. The difference between the heat production of a new-born infant asleep in its basket and crying can be precisely measured. Thus Talbot and Benedict found that the metabolism of the new-born infant is increased on the average by 65 per cent. in crying with its attendant muscular activity. Students of animal nutrition have long realized that the demands for energy of an animal standing are far higher than that of the same beast lying down. This fact must be taken into account in computing the maintenance requirements of cattle and other domestic animals.

Heat production is greatly increased after eating, and the amount of the increase is closely dependent on the nature of the food consumed. For example, the metabolism of a subject may be increased by 25 per cent. after a meal consisting chiefly of carbohydrates, but by as much as 45 per cent. after a heavy protein meal.

It is necessary, therefore, to eliminate all such factors in determining the standards which shall serve as bases of comparison in applied nutritional physiology.

Since the outbreak of the war, and particularly since our own participation in the conflict, the Nutrition Laboratory has, in addition to extensive investigations on the influence of subnormal rationing upon health and efficiency, pushed forward as rapidly as possible its work on the establishment of nutritional standards. One phase of this program has been the statistical investigation of the so-called basal metabolism of the human individual.[1]

Physiologists have gradually come to a general agreement that the heat production at complete muscular repose and in the post-absorptive state—*i. e.*, about twelve hours after the last meal—shall be called the basal metabolism and shall be used as a standard of comparison in the investigation of all the special problems of human nutrition.

[1] The detailed measurements and the statistical constants, with full discussions of pertinent literature, are about to appear in Publication 279 of the Carnegie Institution of Washington. We shall not, therefore, burden this brief outline with references to literature or statistical detail. Two of the diagrams used here are redrawn from this publication.

For several years the Nutrition Laboratory has been engaged in the measurement of basal metabolism in normal human individuals of both sexes and of widely different ages. These have been made with all the modern refinements of method and manipulation. The subjects were in presumably good health. All those with febrile temperature were rejected. All were in the post-absorptive condition. Perfect muscular repose during the short periods required for indirect calorimetry was assured by instruments providing an automatic record of all movements, even those imperceptible to trained observers.

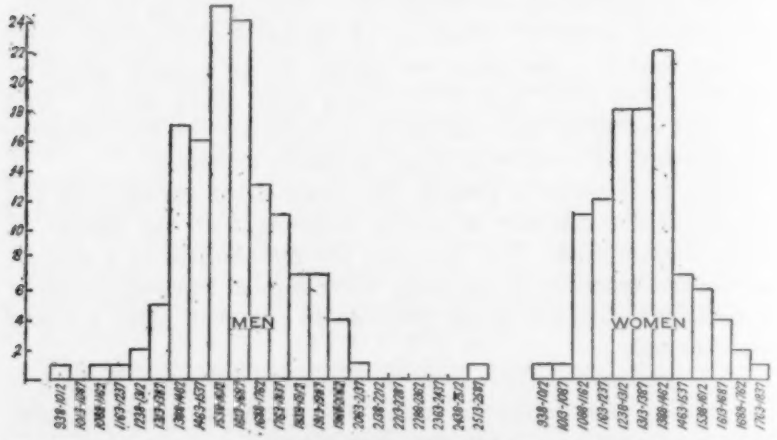


FIG. 1. FREQUENCIES OF MEN AND WOMEN PRODUCING VARIOUS NUMBERS OF CALORIES PER TWENTY-FOUR HOURS.

In carrying out a biometric analysis of the measurements which have been made on 136 men, 103 women, and 94 newborn infants, we have proceeded on the conviction that the widest possible usefulness of laboratory investigations of normal human metabolism will result from basing measurements upon those in presumably good health but otherwise typical of human beings in general. It is only when the subjects used for experimentation are representative of the population at large in type, variability and correlation that the results of laboratory research upon limited series may be safely generalized for rationing or for other practical social applications. An explanation of the statistical tests which have been applied to determine the suitability of the series used in the present investigation would lead us into too great detail for this discussion.

The average basal metabolism per twenty-four hours is as follows:

For 136 men	1631.74 calories.
For 103 women	1349.19 calories.
For 51 male infants	144.55 calories.
For 43 female infants	140.37 calories.

Thus it appears that the basal energy requirements of the American men are a little less than one half of the number of calories (3,300) established by the Inter-Allied Scientific Food Commission as necessary for rationing in the case of men doing average work eight hours per day. They are a little less than half the 3,200 to 3,600 calories used by a group of men at the Springfield Y. M. C. A. college before they were subjected to rationing tests by the Nutrition Laboratory. The average for new-born infants is somewhat less than ten per cent. of that of women.

Human beings differ in their basal metabolism just as they do in stature, weight, pulse-rate and other measurable characters. For example, the 136 men and 103 women showed the daily caloric output represented by Fig. 1. In these polygons the ordinates represent the frequencies of total heat production in calories per twenty-four hours.

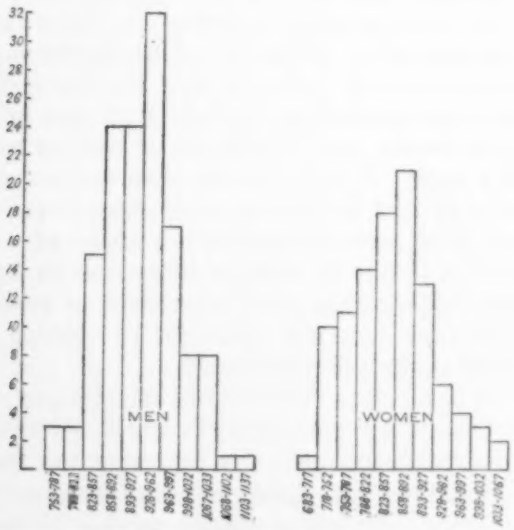


FIG. 2. FREQUENCIES OF MEN AND WOMEN PRODUCING VARIOUS NUMBERS OF CALORIES PER SQUARE METER OF BODY SURFACE PER TWENTY-FOUR HOURS.

The distribution of daily heat production in men and women is represented by monomodal, more or less symmetrical frequency polygons. This result is of considerable interest since it shows that the distribution of the magnitude of human basal

metabolism exhibits the same orderliness that biometric work has shown to prevail in the variation of other biological measurements. When data are somewhat more numerous, it will be profitable to carry the analysis further by fitting theoretical frequency curves to these frequency distributions.

Measured statistically, the variability of these subjects may be expressed by standard deviations of 204.66 calories in men and of 155.18 calories per twenty-four hours in women, or by coefficients of variation, *i. e.*, of standard deviations expressed as percentages of the means, of 12.54 per cent. in men and of 11.50 per cent. in women.

The statement that variation in the total daily heat production of adults is measured by a coefficient of 11.5 to 12.5 per cent. will mean very little to the non-statistical reader until he can compare these with coefficients for characters with which he is more familiar. In our series stature shows a coefficient of variation of 4.39 in men and 3.20 in women, body weight a coefficient of variation of 16.06 in men and 20.35 in women, pulse rate at complete rest a coefficient of variation of 10.99 in men and 12.01 in women. Thus basal metabolism shows a variability far greater than stature but less than body weight and of roughly the same order of magnitude as pulse rate.

Basal metabolism is, therefore, rather highly variable. The reader will have noted, however, that the foregoing polygons and constants are based upon the total daily heat productions of adults in presumably good health but of various body weights, statures and ages. It has already been suggested that basal metabolism is related to these physical characters.

We must now inquire whether the observed variability in heat production is due in part to differences in bodily dimensions. This influence has been considered so great that some physiologists have asserted that heat production per square meter of body surface is a constant.

That heat production expressed in calories per square meter of body surface is not a constant in any exact sense is shown by Fig. 2, in which the ordinates represent the frequencies of total heat production per square meter of body surface as estimated by the Du Bois height-weight chart.

These diagrams show clearly that heat production per square meter, like total daily heat production, is a variable function. In both cases the frequencies decrease as the magnitudes of the constants diverge more widely, in both the plus and the minus direction, from the average for the whole series.

The fact that a large variability in daily heat production

remains when it is reduced to calories per square meter of body surface does not, however, warrant the conclusion that metabolism is independent of bodily dimensions.

To investigate this problem we have merely to group all individuals according to some physical character and to determine whether metabolism changes with variation in the magnitude of the selected physical dimension. For example, Fig. 3 is made by representing the stature and the heat production

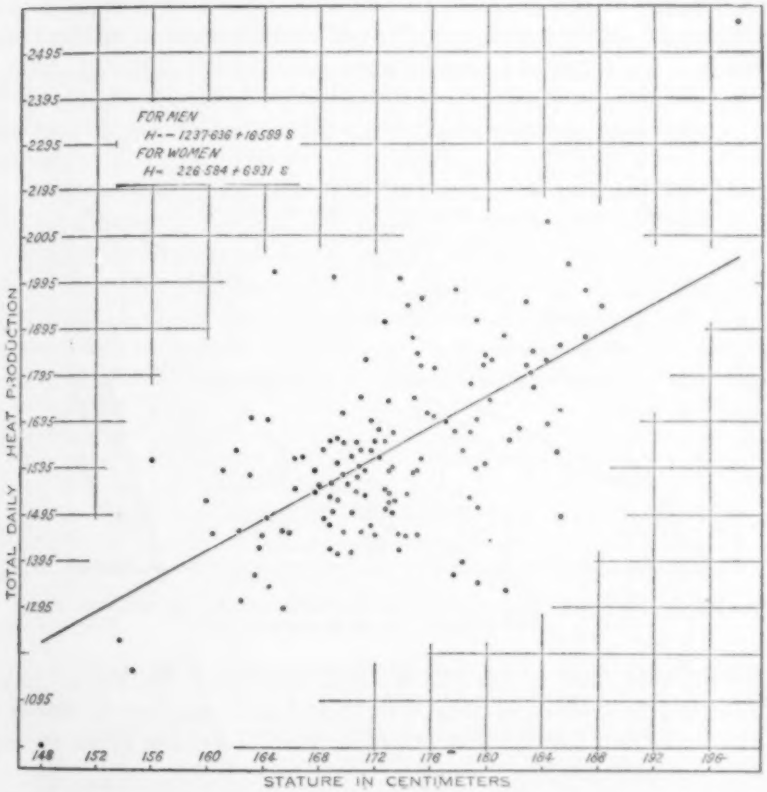


FIG. 3. RELATIONSHIP BETWEEN STATURE AND TOTAL DAILY HEAT PRODUCTION IN 136 MEN.

of each individual on the horizontal and the vertical scales by a dot. It will be seen at a glance that the metabolism of men of any stature is highly variable. Nevertheless there is an orderly trend in the swarm; there is a marked tendency for taller men to show greater daily heat production.

Such relationships may be represented in a different way. Take another physical character for purposes of illustration. One may determine the average daily heat production of indi-

viduals of different body weights, represent these averages by a series of points and smooth them with a straight line. Thus Fig. 4 shows quite clearly that the daily heat production of individuals tends to increase in a sensibly linear manner with their mass.

For exact comparison we must have recourse to some precise method of expressing the degree of relationship between physical characters and basal metabolism. This may be done by the use of the coefficient of correlation which measures the degree of interdependence of two variables on a universally

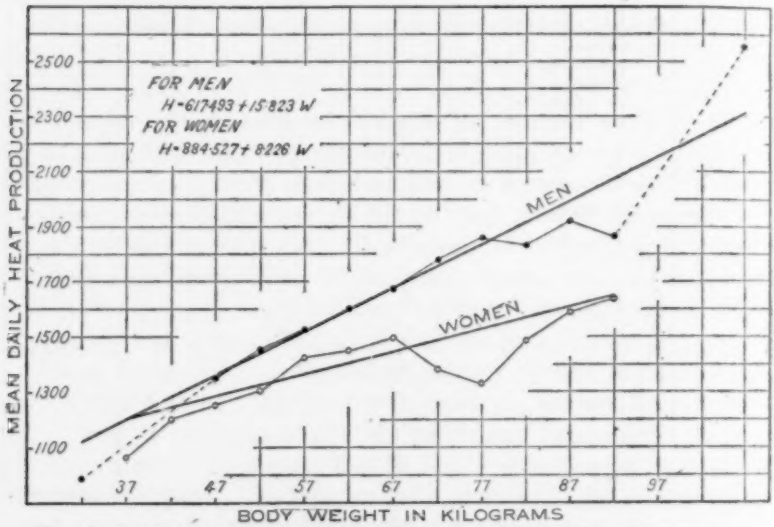


FIG. 4. RELATIONSHIP BETWEEN BODY WEIGHT AND DAILY HEAT PRODUCTION. Actual averages and fitted straight lines.

comparable scale of unity. We find the values for the correlations between stature, body weight and body surface on the one hand, and total daily heat production on the other given in the accompanying table.

Series	Stature and Total Heat-production	Body-weight and Total Heat-production	Body-surface and Total Heat-production
Men (136)	$+0.615 \pm 0.036$	$+0.796 \pm 0.021$	$+0.820 \pm 0.019$
Women (103)	$+0.232 \pm 0.063$	$+0.609 \pm 0.042$	$+0.611 \pm 0.042$
Male infants (51)	$+0.619 \pm 0.058$	$+0.752 \pm 0.041$	$+0.749 \pm 0.042$
Female infants (43)	$+0.743 \pm 0.046$	$+0.808 \pm 0.036$	$+0.809 \pm 0.036$

The coefficients measuring the relationship between body weight and metabolism are in all cases higher than those between stature and metabolism. Body mass is, therefore, a more important factor in determining (in the proximate but not

necessarily in the causal sense) the basal daily heat production of the individual than is a linear bodily dimension such as stature. The correlations between body weight and metabolism and between body surface and metabolism are of approximately the same magnitude. The two characters have, therefore, the same value in indicating the basal metabolism of the subject.

We have just noted that metabolism is correlated with both stature and body weight. Heavier and taller individuals have a larger daily food requirement. But body weight and stature are correlated characters. The interesting question, therefore, naturally arises whether the greater heat production of tall individuals may not be merely the resultant of the relationships between stature and weight on the one hand and weight and metabolism on the other.

This question may be solved by the use of appropriate partial correlation formulæ. We have to determine whether there is a correlation between body weight and daily heat production when correction has been made for the influence of stature, and conversely, to determine whether there is a correlation between stature and daily heat production when correction is made for the influence of body weight. The results are given in the accompanying table.

Series	Correlation Between Weight and Total Heat-production			Correlation Between Stature and Total Heat-production		
	Gross Correlation	Corrected for Stature	Difference	Gross Correlation	Corrected for Weight	Difference
Men (136)	+0.796 ±0.021	+0.687 ±0.031	+0.109	+0.615 ±0.036	+0.321 ±0.052	+0.294
Women (103)	+0.609 ±0.042	+0.580 ±0.044	+0.029	+0.232 ±0.063	+0.045 ±0.066	+0.187
Male infants (51)	+0.752 ±0.041	+0.549 ±0.066	+0.203	+0.619 ±0.058	+0.095 ±0.094	+0.524
Female infants (43)	+0.808 ±0.036	+0.494 ±0.078	+0.314	+0.743 ±0.046	+0.149 ±0.101	+0.594

Since the partial correlation coefficients have sensible positive values, it is evident that both stature and body weight have independent significance in indicating daily heat production. This is a result of great importance, since it underlies the determination of the best formulæ for the prediction of the basal metabolism of the individual.

Let us now consider the relationship between metabolism and age.

The change in the food requirements of the human individual with age is not merely a question of material importance to the clinician, but of great interest to the biologist in its bearing upon the general problem of senescence.

The decrease in basal metabolism with age during the period of adult life has been shown to be well represented by the linear equations.

For men ($N=136$),

$h=1823.80-7.15\,a$, $h_k=28.703-0.112\,a$, $h=1022.17-3.60\,a$.

For women ($N=103$),

$h=1420.47-2.29\,a$, $h_k=28.308-0.124\,a$, $h=924.25-2.96\,a$.

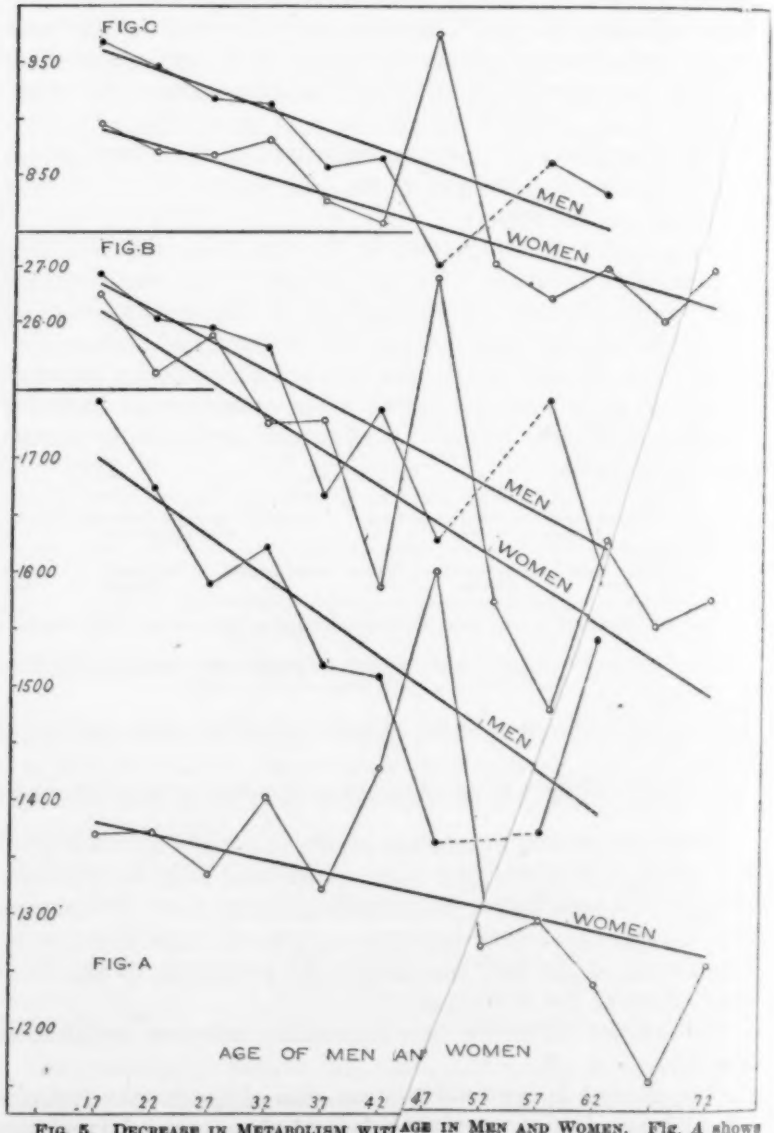


FIG. 5. DECREASE IN METABOLISM WITH AGE IN MEN AND WOMEN. Fig. *A* shows the decrease in total daily heat production, *h*, the decrease in calories per kilogram of body weight and *C*, the decrease in calories per square meter of body surface. The straight lines are due to the equations given in the text.

where h = total heat production in calories per twenty-four hours, h_k = calories per kilogram of body weight, h^D = calories per square meter of body surface, as estimated by the Du Bois height-weight chart. These lines are represented in the three diagrams of Fig. 5. While the actual mean heat productions are distributed about these lines with very great irregularity because of the small number of individuals (considered from the statistical, not from the physiological, side) it is doubtful whether equations other than those for straight lines could be advantageously employed.

These equations show that in men the daily heat production decreases about 7.15, while in women it decreases about 2.29 calories per year. Women are smaller than men and have a lower heat production. When the decrease in metabolism with age is expressed in calories per kilogram of body weight or in calories per square meter of body surface, the results for the two sexes are more nearly identical. The linear nature of the change in metabolism with age during the period of adult life fully substantiates the conclusions of biological writers concerning the greater continuity of senescence in the vertebrates as compared with lower organisms. It also shows that during adult life senescent changes take place at a sensibly uniform rate.

Throughout the entire history of the investigation of the metabolism of the warm-blooded animals, the question of the relationship between the body surface area of the organism and its heat production has been a center of interest. Even before the development of adequate experimental methods of investigating the energy transformation which takes place in the body of the vertebrate organism, the possible relationship of body surface area to heat production was a subject of speculation. Physiologists recognized that a whale or an auk in the arctic exposes relatively far less surface for the loss of heat than a flying fish or a humming bird in the tropics. Attempts were consequently made to explain the relatively higher food requirements of small as compared with large animals by the relatively larger surface exposed for heat loss in small organisms.

Newton's law of cooling made a strong appeal to the imagination of earlier physiological writers. It is not surprising that, impressed as they were by the relative constancy of body temperature in the warm-blooded animals, they conceived of heat production as proportional to heat loss as a means of maintaining constant body temperature, and came to look upon heat loss as determined by body surface area, and to consider heat loss as determining in its turn heat production.

This is not the place to trace the history of the so-called body surface law, according to which heat production per square meter of body surface is a constant. It has been widely maintained since the days of the speculative writings of Bergmann, the comparative studies of Rameaux, and the experimental investigations of Müntz, Rubner and Richet. Of recent years this so-called law has assumed practical importance in that writers have maintained that the closest approximation to the basal metabolism of a subject is given by

$$h = \bar{h}_s s,$$

where h is the required daily heat production, $\bar{h}_s$ the average heat production per square meter of body surface in a standard series and s the body surface of the subject under consideration.

The reader may be inclined to inquire why such a formula is of practical significance. The answer should be evident on a moment's reflection. Suppose the clinician wishes to investigate the influence of some disease, for example diabetes, on the metabolism. A subject is selected from the hospital ward, placed in the respiration chamber, and his daily heat production determined. This is merely a technical matter. The interpretation of the result presents a much more serious problem. The caloric output of the subject in a pathological state has no significance as indicating the influence of disease upon metabolism until it can be compared with a normal value. With what normal constant shall it be compared? Naturally, with that which would be expected for the same individual in good health. Thus the *theoretical* metabolism of the subject in health must be taken as a basis of comparison for his actually measured metabolism in disease before one can draw any conclusions whatever concerning the influence of the disease.

Again, suppose that stringent rationing is under consideration. What ration shall be allotted to individuals of various sizes? Clearly, both the most just and the most advantageous procedure would be to allow them food proportional to their physical needs.

Now one of the crucial tests of the validity of a law is its capacity for predicting the unknown. If the "body surface law," expressed by the above formula, serves to predict the heat production of a subject more precisely than any other formula, it must certainly take its place as one of the most important empirical laws in nutritional physiology.

This problem has been investigated in great detail in the extensive data collected at the Nutrition Laboratory during the

past decade. These are now so numerous that it is possible to use one fraction of the records as a basis of prediction equations, and to test the validity of these equations by considering the metabolism of other actually measured individuals as unknown, calculating their caloric output by the various methods, and determining which formula gives the closest prediction. That formula which estimates the metabolism most exactly from measurable physical characters must be looked upon as the most valuable empirical law.

It must be admitted that the "body surface law" has given excellent results. If, however, there be no purely physiological basis for assuming a causal relation between body surface and heat production it would seem desirable, if possible, to replace this formula by a more rational one.

The foregoing analysis has shown that weight, stature and age all have independent significance for predicting the metabolism of the individual. Availing ourselves of the constants showing the independent relationship between these easily ascertainable characters and metabolism, we deduce the following multiple prediction equations:

$$\text{For men} \quad h = 66.473 + 13.752\,w + 5.003\,s - 6.755\,a.$$
$$\text{For women} \quad h = 665.096 + 9.563\,w + 1.850\,s - 4.676\,a.$$

where w = body weight in kilograms, s = stature in centimeters, and a = age in years.

These equations make possible the closest prediction of the daily caloric output of an unknown subject. They are particularly well adapted to practical work. To calculate the most probable metabolism of any subject it is only necessary to substitute the actual values of weight, stature and age in the equation; for example, A. S. F. is a man 21 years old, weighing 69.3 kilograms, and 169 centimeters in height. His most probable daily heat production will therefore be given by

$$h = 66.973 + (13.752 \times 69.3) + (5.003 \times 169) - (6.755 \times 21) = 1723 \text{ calories.}$$

His actually measured heat production was 1,733 calories, or there was an error of only 10 calories per twenty-four hours or of 0.6 per cent. in predicting his metabolism from two physical characters and age.

The result is unusually good. K. G. M. is 32 years old, weighs 68.8 kilograms and is 171 centimeters tall. His daily heat production should, therefore, be given by

$$h = 66.473 + (13.752 \times 68.8) + (5.003 \times 171) - (6.755 \times 32).$$

The equation gives 1,652 calories as compared with 1,889

calories actually measured. This is an error in prediction of 237 calories, or of 14.3 per cent., and is next to the worst result secured by the use of our formula in a series of thirty-one tests on subjects measured subsequent to its development. For only five of the thirty-one individuals was the error of prediction over ten per cent. The average computed heat production of the 31 subjects was 1,661.03 calories per day, whereas the average measured heat production was 1,653.35 calories, or 7.68 calories per day less. If the individual differences between the observed and the measured heat productions be considered without reference to sign, *i. e.*, without regard to the fact that some are too low, whereas others are somewhat too high, we find that there is an average difference of ± 87.87 calories. Thus by the use of this biometric equation we have been able to predict the heat production of a series of subjects from two physical characters and age alone with an average plus or minus error of only 5.30 per cent.

We may illustrate the practical application of such multiple prediction equations[2] in clinical calorimetry by the values of

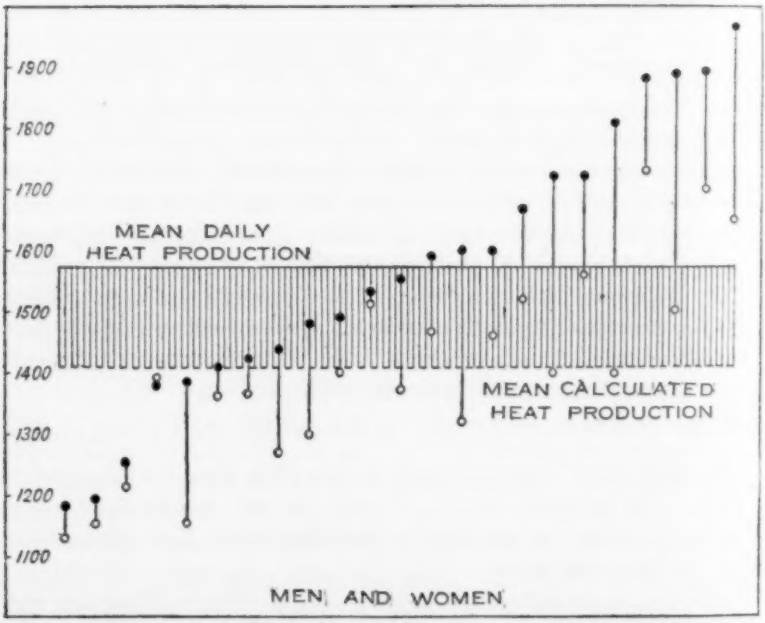


FIG. 6. COMPARISON OF METABOLISM OF DIABETICS WITH NORMAL STANDARDS.

[2] These equations have been tabled for values of weight from 25.0 to 124.9 kilograms, for stature from 151 to 200 centimeters and for age from 21 to 70 years. Thus the most probable basal metabolism of an unknown subject may be easily determined.

the daily heat production of a series of 23 diabetic subjects investigated by Joslin and Benedict. These are represented on the scale at the left by the position of the solid dots in Fig. 6. The patients are arranged in order according to the magnitude of their daily heat production. The values given by the equations are represented by the position of the circles. In every case but one the metabolism of the diabetic is greater than that which would be expected for a healthy subject of like physique and age. The solid and the broken lines show the averages of the actual and the control heat productions. The average of the actually determined values is about 1,572.2 calories, or 11.55 per cent. higher than the average of the standard controls which is 1,409.4 calories. The influence of diabetes on the basal metabolism is clearly demonstrated.

As another illustration of the usefulness of these equations we may take the data for a series of twenty-two vegetarians, eleven men and eleven women, studied by Roth and Benedict. The question at issue is: Does, or does not, a vegetarian diet modify the basal metabolism?

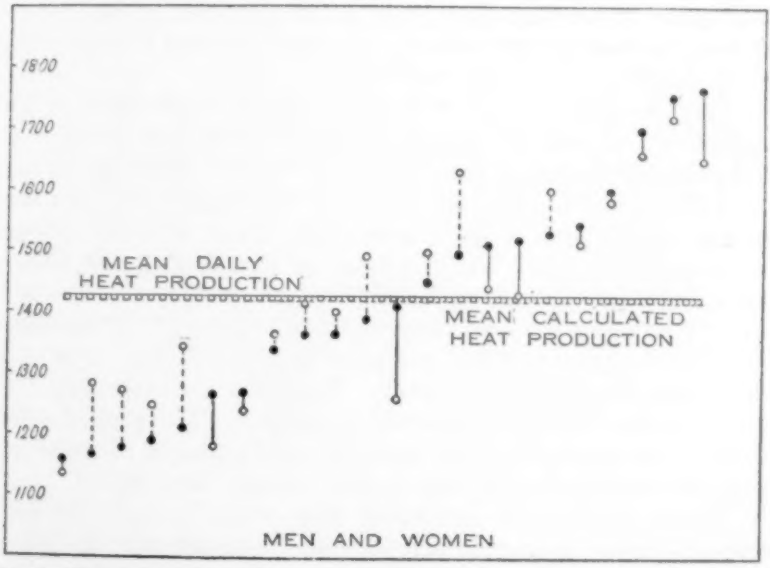


FIG. 7. COMPARISON OF THE METABOLISM OF VEGETARIANS WITH NORMAL STANDARDS.

Fig. 7 shows the actual heat productions (solid dots) and the computed heat productions (circles) of the men and women. Since the equations used in computing the predicted values are for men and women respectively the two sexes may be treated

together. In eleven cases the actual heat productions are higher, while in eleven cases they are lower than the values computed from the equations. The means of the actual and computed heat productions are practically identical. These results show clearly that there is no appreciable influence of vegetarian diet on the basal metabolism.

Other illustrations might be given. Perhaps the most interesting is the use of the equations in investigating the difference in the metabolism of men and women. This problem, which has attracted the interest of a number of investigators in the past, has been reconsidered from all sides on the larger series of data now available. The results show that the average daily (twenty-four hours) basal heat production of the 136 men investigated is 1,632 calories, whereas that of the 103 women studied is 1,349 calories. Thus the daily heat production of women is about 300 calories less than that of men. But women are smaller than men. If correction for body size be made by expressing heat production in calories per kilogram of body weight, it is 25.7 calories in the men as compared with 24.5 calories, or 1.2 calories per kilogram less, in the women. The men show an average daily heat production per square meter of body surface of 925 calories as compared with 850 calories, or 75 calories less, in the women.

The most critical test of the existence of a difference in the metabolism of men and women is that furnished by comparing the actually measured metabolism of women with that calculated from biometric equations on the assumption that they are men of like stature, weight, body surface, age or combinations of these characters. The diagrams in Fig. 8 show the differences between the actual metabolism of women (circles and lower lines) and the heat production calculated on the assumption that they were men of comparable physical characters and age (solid dots and upper lines). Diagrams *A–C* represent the results given by three different equations. The shaded zone shows a deficiency in the actual heat production of the women, who are classified according to body weight, throughout.

These and further statistical tests which can not be discussed in detail show conclusively that the metabolism of American women is lower than that of men. Our results show that the differentiation of the sexes is not evident in infancy. They do not confirm the conclusion of Sondén and Tigerstedt that the difference between men and women tends to disappear with age. Instead we find the difference in the metabolism of men and women well marked throughout the period of adult life.

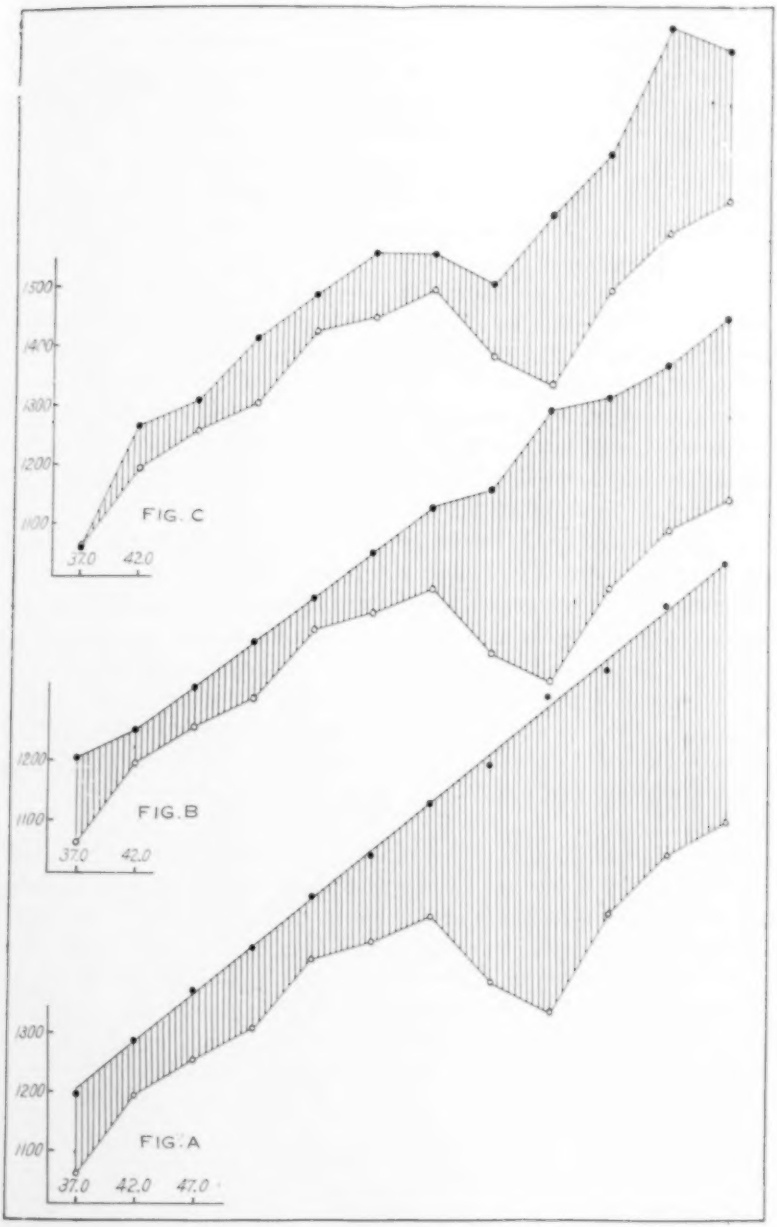


FIG. 8. COMPARISON OF METABOLISM OF MEN AND WOMEN.

This brief outline may serve as an introduction to some of the problems which require consideration in the establishment of normal standards for work in human nutrition.

It would be quite unfair to leave the reader with the impression that the basal metabolism is a fixed and unchangeable physiological constant. While extremely valuable as a basis of comparison, the basal metabolism is subject, not only to great variation from individual to individual, but to modification in response to profound experimentally induced changes in the level of nutrition of the subject. Thus a man who underwent a 31-day fast at the Nutrition Laboratory, during which he took no food whatever and only about 900 cubic centimeters of distilled water per day showed a decrease of 28 per cent. in his basal metabolism.

A more recent investigation of the influence of severely limited diet, undertaken by the Nutrition Laboratory on squads of men who volunteered for this purpose at the International Y. M. C. A. College at Springfield, Mass., in response to the need for more exact information concerning the influence of war-time diet on health and efficiency, has shown a striking influence of reduced diet accompanied by rapid alteration of body weight on the basal metabolism. One squad was kept for a period of four months on a restricted diet with an energy content of one half to two thirds of the requirements prior to the fast, when the normal demand of the men ranged from 3,200 to 3,600 net calories. After a reduction of only 12 per cent. in weight, 1,950 calories only were required to maintain this weight.

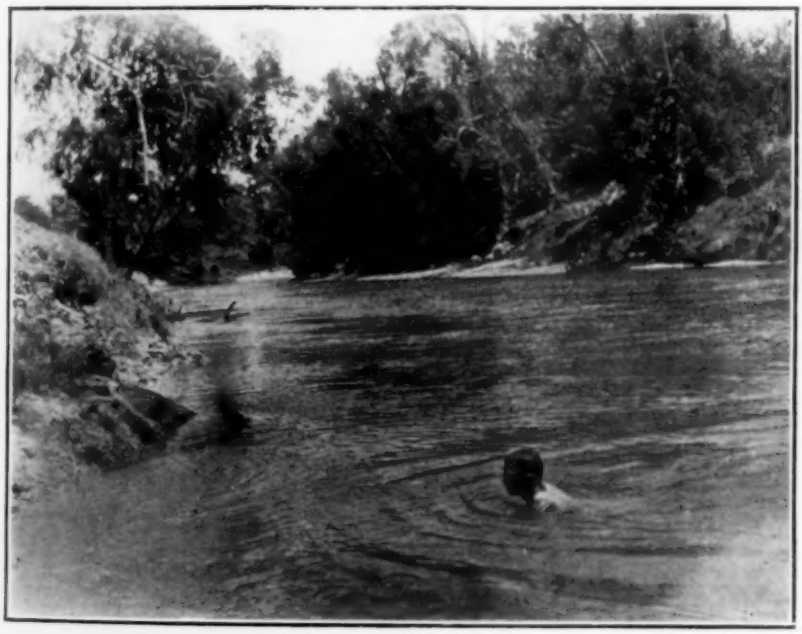
Notwithstanding this fact, and the wide variability in basal metabolism in whatever units it may be expressed, the basal metabolism when measured on large numbers of individuals in good health and living under normal conditions, and described in terms of the proper biometric constants and equations, furnishes a valuable, and as yet the only available, standard of comparison in the investigation of all the special problems of energy requirements in human nutrition.

AN ENTOMOLOGICAL CROSS-SECTION OF THE UNITED STATES. II.

By Professor J. CHESTER BRADLEY

CORNELL UNIVERSITY

If one were to draw a curved line from Austin, Texas, through San Marcos, San Antonio and Uvalde to Del Rio, he would be tracing the south and southeastern escarpments of an elevated limestone region, known as the Edwards Plateau. In this area many rivers of clear water take their origin, and as is the way in limestone countries, flow underground until the escarpment is reached. About 30 miles north of San Antonio at the old German community of New Braunfels, what is perhaps the finest of these rivers comes pouring out of the cliffs in a series of magnificent springs. It is the Comal River and with all haste it empties its beautiful waters, after a very



GUADALOUPE RIVER AT VICTORIA, TEXAS. The river is approximately the border between the humid and arid regions of Texas. Its clear blue waters were no more resistible to us than to a party of negro boys and girls, who *sans* everything in the way of clothing, enjoyed themselves noisily above our camp.

short course, into the Guadalupe. Calladia grow wild along the bank, and quite a jungle of semi-tropical plants, while its course is lined beneath with the most beautiful profusion of aquatic plants that I have ever seen. At these Comal springs we took our first real rest from the road and tarried several days. Dr. Wheeler has described the spot in his paper on the fungus-growing ants of North America. Here some years ago he found a very interesting association of ants, including species hitherto known only from more tropical regions.

While at New Braunfels we drove one day to a sanctuary up in the hills, known as Anhalt. The kindly Father who greeted us, when he discovered that we were entomologists, presented us with a small, but interesting, collection of the beetles of the neighborhood, which unfortunately was in an advanced state of destruction by *Dermestes*. We climbed up to a small chapel on the summit on a knoll and there, clinging to the sides of an old well, observed great masses of harvestmen and smaller groups of *Ceuthophilus*. We lowered Needham into the well by a rope and he secured many. When the harvestmen were slightly disturbed they seemed to teeter up and down in a rhythmic sway, but perhaps the rhythm was fanciful. Meanwhile Shannon was attracted by a shrill elusive buzzing, which he finally discovered emanated from a fly poised in front of a live oak. Others were located, but always they darted away with great swiftness as soon as observed. When at last one was caught it proved to be *Hirmoneura flavipes* Williston, a nemestrinid, one of the rarest of flies. Dr. Bequaert and I joined in the chase, and after we learned how to catch them, we obtained among the three of us quite a goodly series, of both sexes. Always they were poised in the air in front of a tree, emitting a peculiar shrill humming. However, I discovered one female crawling about over dead twigs as though hunting a place to oviposit, but I could not observe that she did this. Dr. Bequaert saw some *in copula*, the pair hovering in the same way. Another capture at Anhalt was *Eburia stigmatica*, a longicorn and also the magnificent green *Callichroma plicatum*.

During our stay at New Braunfels we collected in the trap-lantern a fine series of *Fernaldella fimetaria* G. & R., a geometer, common in Texas, but interesting as representing the only genus of its subfamily; it was unrepresented in our university collections. There also were nine specimens of a striking little aquatic Pyralid of the subfamily Nymphulinæ, representing a genus new to science, or at least to North America. Accord-

SOURCE OF THE COMAL RIVER IN ENORMOUS SPRINGS AT NEW BRAUNFELS, TEXAS. Here Dr. Wheeler has found ants of a distinctly tropical affinity. The banks stand thick with calladia, and the limpid waters flow over a bottom hidden by aquatic vegetation of astonishing luxuriance. Photograph by P. A. Munz.

ing to Dr. Forbes it is related to Elophila in structure and marks, with reduced venation and long porrect palpi. Here we caught also *Cobubatha flavofasciata* Grote, an interesting noctuid, the commoner *C. quadrifera*, and for the first time *C. luxuriosa*, which we were destined to take on two or three later occasions, westward as far as the Dragoon Mountains of Arizona.

Our visit to New Braunfels was made both more pleasant and more profitable by the kind hospitality of some old friends of Dr. Wheeler's, the Dittlingers, who showed us many courtesies, piloting us around to the most favorable collecting grounds.

"ANHALT," in the hills near New Braunfels, Texas.

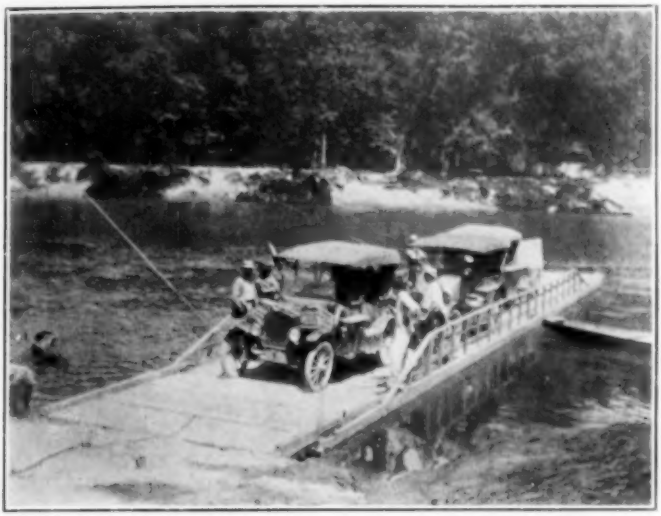
CHURCH AT YSLETA, TEXAS. One of the oldest churches on the continent. Photograph by R. C. Shannon.

On the night of June 30 we camped in a most charming park of small conifers near Helotes, Texas, close to a dry stream. This is eighteen miles from San Antonio, in the hills, and a most attractive locality. In the early morning, upon arising, we observed and captured several specimens of a smaller nemestrinid, *Hirmoneura texana* Ckll. These were also hovering in the air before the conifers and were difficult to catch. Here we also caught some noteworthy butterflies, the semitropical *Kricogonia lyside*, in both sexes, the male typical, but the female belonging to the variety *unicolor* G. and S., more of the then undescribed *Callephelis perditalis* B. & McD., which we had previously taken at Sutherland Springs; a typical *Anosia strigosa*, an arid region form, which here must have been at the eastern limit of its range; and *Melittia calina*, a much confused species, really belonging to *Phyciodes*, sometimes known as *ubrica* Stk. Mr. Knight found some unusually fine Hemiptera at the light-trap here, among them a new genus and species of the very rare family Isometopidæ, since described by E. H. Gibson from specimens from Brownsville as *Lidopus heidemanni*, a new species of the typical genus Isometopus of the same family, and a mirid of the South American genus *Zoshippus*. Tingitidæ that he found on *Malvaviscus drummondii* have since been described by C. J. Drake as *Calotingis knighti*. There were more strange Hemiptera here than at any other place.

Early we were on our way westward, along the general course of the Southern Pacific Railway. Our first night camp was at Sabinal, on the Sabinal River. Alongside of the road, as we stopped, was awaiting a gopher turtle, *Gopherus berlandieri*, the only one that we observed. Here we found a splendid colony of *Atta septentrionalis*, the Texan leaf cutter ant, working on the leaves of the small native walnut (*Juglans rupestris*). Their well marked paths extended from the nest in diverse directions, well paved with walnut leaves. These were the first leaf cutter ants I had ever seen at work and were of absorbing interest to me personally. In the morning at 6:30 of the clock, *Hirmoneura texana* appeared again.

The west fork of the Nueces River proved an enticing spot for lunch and good collecting. There were several striking species of flowers along the bank, and clear, swift-running water in the stream. Among birds we noted: blue grosbeaks, Mexican goldfinches, and the little Texan kingfisher. On desert willow (*Bignonia*), which was blooming lustily, we collected *Tibicen delicata* Osborn. By night, we reached the Devil's

River and camped along the bank of this most remarkable of streams. Imagine the effect of coming suddenly from the hot and parched desert upon the wall of a cañon or huge barranca, and to find upon descending to its bottom no sandy wash, or standing pools or trickling stream, but a river of large dimensions and volume, swiftly flowing, clear, blue and cool. After



CROSSING THE PEARL RIVER FROM MISSISSIPPI INTO LOUISIANA. Photographed by Anna A. Wright. The trip through Louisiana is described in the earlier part of the article.[1]

dark I searched a sand bank with a flashlight for females of *Photopsis*. The males of this genus of Mutillidæ are nocturnal and come commonly to light, but the females are but very rarely collected, and little is known of their habits. I was rewarded by finding two running busily about over the sand. Near here, Knight collected a single male each of *Tibicen montezuma* Distant and *Cacama valvata* Uhler, the latter a species of cicada not taken elsewhere on the trip. In the trap-lantern

[1] By mistake the names of the photographers were omitted from the legends under the illustrations in the first part of this article. The photographs taken by others than the author were: By Ralph Wheeler, "Ezra Cornell," "The John Harvard," "Sandy Wash in Yuma Desert," "Crossing the Gila River," "One of the Fords," "Ups and Downs North of Phœnix"; by P. A. Munz, "A Muddy Road through the Chopawampsic Swamp," "In the Catalina Mts." (The titles under these two pictures are incorrect, and should read, respectively: "Cypress Swamp, Louisiana," and "A Muddy Road through the Chopawampsic Swamp in Virginia"), "Photographing a Rattler"; R. C. Shannon, "Post Cañon"; Mrs. A. H. Wright, "The Endless Road," "Texas Pass."

COVINGTON, LOUISIANA. Some lumbermen are floating a log raft down the stream. Photograph by Anna A. Wright.

catch appeared *Aleptina inca*, described by Dr. Dyar from Arizona in 1902 and the only species of the genus. It was new to the university collection. In this western Texas region scissor-tailed flycatchers are common, and we saw an occasional *Pyrrhnoloxia texana*, one of the most beautiful birds seen on the trip, an ally of the cardinal.

Following north along the general course of the river we

AVERY ISLAND, the bird sanctuary near New Iberia, Louisiana. Photograph by P. A. Munz.

CYPRESS ALONG THE PEARL RIVER, LOUISIANA. Photograph by P. A. Munz.

camped near Juno. Again we found a most attractive spot, and although it was a true desert region there were most beautiful ferns of several species. A sweet-scented flowering tree attracted numerous butterflies as well as *Pepsis* and other wasps. We caught two specimens of a magnificent metallic green longicorn, *Callichroma plicatum*, looking as though it were a stray creature from the tropics, with its gorgeous livery. A most amusing incident occurred here. So far we had not seen a rattlesnake. Within a few feet of camp at dusk, Dr. Bequaert, stooping to examine a supposed curious cactus, was greeted with the sharp buzz of a rattle's warning. His exclamation drew the entire camp, and the specimen was duly dispatched and admired. After the excitement had subsided the doctor thought he would have a little joke upon the others and purely in jest, pointed suddenly toward the ground, exclaiming "Look out, there's another!" Suddenly from exactly where he pointed, another rattle sounded. I should like to have had a yardstick to have measured how far *he* jumped to find his jest come true! Both specimens (*Crotalus atrox* and *confluentus*) are now in the collection of Cornell University. It is interesting that they should have belonged to different species.

We celebrated the fourth of July by crossing the Pecos. Trans-Pecos, Texas! What scenes these words conjure to the naturalist. At that time the country had been so long suffering from drought that the cattle were dying by the thousands, their carcasses everywhere in most pitiful evidence. From New Braunfels we had shipped our tents home, preferring to sleep thereafter in the open. They had given us protection from mosquitoes which were not to be expected in the desert, while as to rain—well we had had none since leaving Virginia, and the summer showers of the desert, if we met with any, we thought would be no inconvenience. Poor greenhorns that we were! From now on we were seemingly continually playing tag with thunderstorms, and sleeping in *swarms* of mosquitoes! Reader, have you ever seen a desert thunderstorm? I will describe one, calmly. It rains *pretty hard* where you are, but not before you nor behind you. Or it rains a little harder before you or behind you, but not where you are. These storms are very particular about *where* they rain—they would not think about trespassing on one another's territory. They go wandering about over the desert, three or four of them sometimes at once, avoiding each other and looking like huge columns of smoke. But where they do rain they *rain*. They

"Simon Henry" an action in the Chopowompsic Swamp in Virginia. Photograph by P. A. Munz.

dump the water out—well as I said before right hard, anything to get rid of it, and that quickly. And where they rain nothing travels for a while. Mud has its qualities and desert dobe is genuine. The vacillating streams, having neglected to provide for themselves a course while the weather is dry and they have time to think it over, are called upon when it rains to decide in a hurry. That is the hour of their glory. They laugh at the lordly desert and cut across it at will, carrying rocks, boulders,—half a mountain side. Now *they* rule by the power of might, and the rest of creation must sit and await their pleasure. Well, one would not have chosen otherwise, for the rains brought leaves out on the desert plants, flowers everywhere, and with them insects. Fortunate were we, that when we could not travel we could collect.

This was a fine region for interesting Cicadidæ. Along the Pecos River were *Tibicen deliçata* and *Proarna venosa*. The latter was abundant from this region westward into New Mexico. At Ft. Stockton and from there also westward into New Mexico *Tibicen eugraphes* Davis were abundant on mesquite, screw bean, etc. At the bridge over the Pecos Dr. Bequaert caught a remarkable tabanid, *Silvius pollinosus* Williston. We camped on the desert some twenty miles from Sheffield. Again we found two rattlesnakes (*Crotalus atrox*) after dark, close to the camp. We came upon them while hunting with flashlights for Mutillidæ and Orthoptera. On the fifth of July we ate lunch at a little stream, where attractive looking dragonflies were abundant. We camped at Chancellor within sight of the Comanche Mountains, and well on toward the Ft. Davis range. Cicadas were very abundant, singing on the mesa after sundown in a long continued chorus, like the shrill rattle of a rattlesnake. Tarantula hawks (*Pepsis*) were also very abundant.

In the Fort Davis Mountains we had our first brief glimpse of the fauna and flora of a desert mountain range. According to Mr. Rehn the affinities of these mountains are strongly with the more northern Rockies and divergent from the Chisos Mountains to the south, which we should have visited had time permitted. In Musquiz Cañon near Ft. Davis we collected in a creek during a thunderstorm. Parnidæ (*Dryops*) and other aquatic Coleoptera and Hemiptera were very abundant. The scenery here was suggestive in its strange rock formations of the Garden of the Gods or of Texas Pass in Arizona which we were to see later. We spent a day well up Limpia Cañon, but owing to the excessive drought it was not very fruitful.

We had hoped for *Plusotus* but were disappointed. Enormous *Allorhina mutabilis* kept buzzing around the oaks. In the trap lantern was an interesting crambid, *Eufernaldia cadarella* Druce [*argenteonervella* Hulst]. The tree *Uta* (*U. ornata*), a scaly lizard related to our eastern swifts, we found in these mountains, and subsequently at two stations in Arizona.

The night of July 7 we camped on grazing land some miles northeast of Valentine, close beside a wash filled with bushes, several of which were in bloom. In the morning Dr. Bequaert and I found admirable collecting for Hymenoptera in this wash. There was a very populous colony of a small *Stizus*. One small tree attracted great numbers of flies. From time to time, resting upon its leaves and evidently attracted by the flies, came specimens of a *Mellinus*—always a rare wasp. Some fine bees were visiting the flowers. Finally, on the bank, several cacti infested with borers yielded a number of specimens of the tenebrionid-like longicorn *Monilema*.

At Sierra Blanca, in the road at night I observed a very populous colony of a pale yellow nocturnal honey ant, *Myrmecocystus mexicanus*. In a flooded creek Dr. Wright found several interesting amphibia; two species of spade foot toads, *Scarpiophorus couchi* and *S. hammondii*, were breeding, and there were three species of *Bufo* (*cognatus*, *compactilis*, and *woodhousei*), of which one was breeding. During the following morning we observed, growing along the roadside, a small white flower, *Lepidium eastwoodiæ*, which was attracting great numbers of small aculeate Hymenoptera. Dr. Bequaert and myself also collected two magnificent species of large bees of the genus *Hemisia* (*H. rhodophus* Cockerell and *morsei* Cockerell) on the large heads of *Centaurea americana*. This was done while waiting for a freight to get out of our way, and the others were doubtless vexed at the delay! In this region and westward flowers of the allthorn (*Koeberlinia spinosa*) afforded a wealth of Hymenoptera, but especially Philanthidæ and *Pepsis*. At night the pepsids would sleep among them, but during the day the bushes became the scene of an incessantly active,—extremely active, host of wasps. To catch them in their quick and nervous flight here, there and away amongst the innumerable unyielding thorns which alone compose the allthorn bush was no easy task.

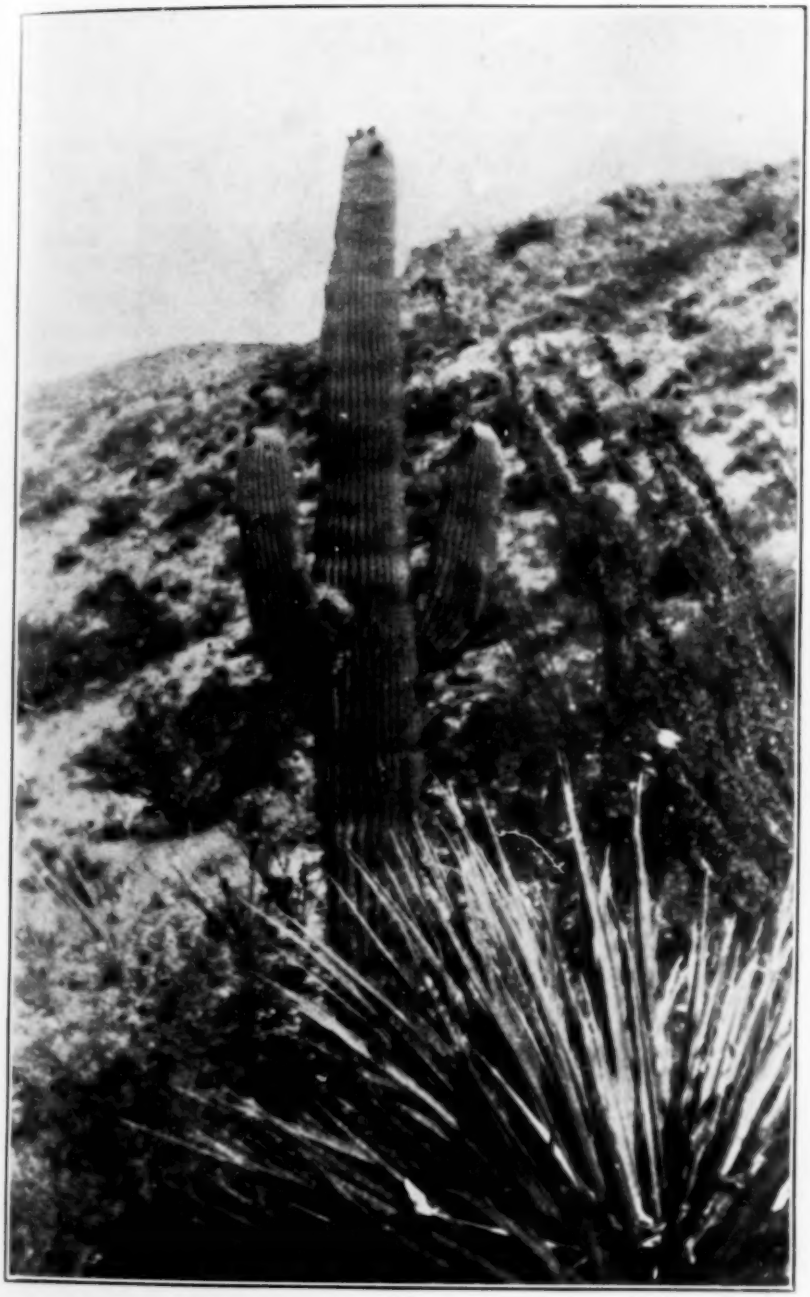
At Fabens, in the irrigated country east of El Paso along the Rio Grande, Dr. Bequaert was so fortunate as to make one of the really noteworthy captures of the trip—a small noc-

turnal bee, at night. It is probably a new species which the doctor will publish in due course—a tiny species of the straw-yellow color which is characteristic of nocturnal Hymenoptera and with great ocelli. At one point along the road hundreds of winged harvester ants, *Pogonomyrmex* sp., were observed clinging together in great masses, attached to branches of a mesquite tree.

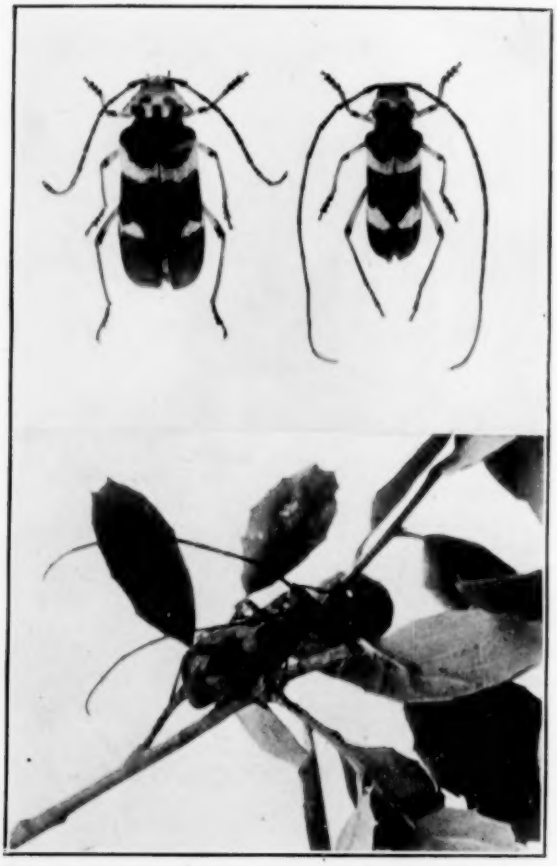
While the Buick was having a spring reset at El Paso, Dr. Bequaert had opportunity to collect in the irrigated fields along the Rio Grande ten miles north of the smelter, and obtained among other fine wasps, a single male of the very rare scoliid wasp, *Engycistus rufiventris* Cresson, described from lower California and the only known representative of its anomalous genus, unless, as has recently been stated, it really belongs to the South American *Pterombus*.

On the eleventh we camped near Mesilla Park. Dr. Wheeler discovered a *Trachymyrmex*, one of the small leaf-cutting ants. Each individual was transporting a fragment of a stem or dried leaf. Their motions were slow and hesitant. With some difficulty we found the entrance of their colony, merely a tiny orifice in the earth. Close at hand, we collected a number of specimens of a very large *Trox* from the carcass of a coyote. In the trap-lantern were: *Heteranassa mima*, a genus and species of Noctuidæ new to the university collection; *Conochares interruptus*, probably a variety of *C. arizonæ*, which we took later in swarms in western Arizona, but representing another noctuid genus not in the university collections; *Trichocosmia inornata* Grote, a third noctuid.

The next morning we crossed the Rio Grande and ascended over the high mesa, traversing a highly volcanic region. At Aden *Proarna venosa*, a small cicada, was abundant on a desert grass; we collected a fine series. Whip-tailed lizards were in numbers at Aden, as at many other desert localities, they being very abundant and characteristic features of the desert life. We obtained two species here, *Cnemidophorus perplexus* and *C. melanostethus*, and a third species, *C. tessellatus*, at Deming, just beyond. They are mostly of dark color with bluish mottlings or lines, and are known by their exceedingly long tails. At our night camp near here ant-lions were numerous, attracted by the lights of the machine or flying to our tent lure. The males of *Brachycistis*, a genus of nocturnal Myrmosidæ also came to the light here in numbers, as they did nearly every night westward. The capture of these was personally one of my chief aims in undertaking the trip, and the



GIANT CACTUS OR SUARELO, one of the most characteristic features of the landscape of southern Arizona. Photograph by Ralph Wheeler.



Crioprosopus magnificus LEC. Photographs by Prof. E. O. Essig.

lure as well as the lantern swarmed not only with these but many other interesting insects. Among them may be mentioned *Saluria ostreella* Hulst, looking deceptively like *Eufernaldia caderella*, but in reality an anerastiid, and a geometer which has since been described by Barnes and McDunnough under the name of *Eucestia marcata*.

We crossed New Mexico in a little over two days and left it on the morning of the fourteenth, after passing through the town of Steins, which will long linger in our memories as a synonym for squalor and dreariness. Piles upon piles of empty tin cans bore mute witness to the pitiful gastronomic debauchery of the residents. The road led into a backyard and stopped and we drove around, lost amid goats, sodden children and innumerable cans, seeking an outlet. Finally we

discovered that the transcontinental highway turned out through an alley on to the front side of a row of buildings, from which we were apathetically, if not hostilely, surveyed by the leisure class from the stoops. The insects were better, for, near here, the pods of *Acacia greggii* secreted a nectar which attracted many Hymenoptera. The previous day, at Deming, Needham captured a large moth of a desirable species, *Gloveria arizonensis*.

On the afternoon of the fifteenth we made camp for a several days' stay near the mouth of Post Creek, close back of the States Reform School at Fort Grant at the base of the Pinaleno Mountains. Culminating in Mt. Graham with an altitude of 10,510 feet, these are the highest and most extensive ranges of southern Arizona. In their higher slopes they are heavily timbered. As low as our camp the creek was still a splendid flowing stream, well bordered by oaks or other trees, while in the cañon further up the vegetation became denser and more humid in character. We

FOREST IN THE CATALINA MOUNTAINS.
Photograph by P. A. Munz.

MARTIN HOUSES MADE FROM GOURDS SUSPENDED TO THE CROSSBARS ON THE POLE. These are seen in many parts of Alabama and Georgia on the coastal plain.

YUCCA. These stately plants grace and beautify the desert ranges. Far above out of reach their waxen flowers draw honey-gathering wasps, bees and butterflies.
Photograph by P. A. Munz.

followed up to where it became of a distinctly transition type.

Never in my life have I beheld a glory equal to that of some of the storms and ensuing sunsets that marked the close of the days. Across the distant lying plain of the Arivaypa the storms would sweep, now involving the Galiuro range on the other side, now skirting the mountains on which we stood, until the sun, setting, lit both rain clouds and the distant gray curtains of falling rain themselves in one vast crimson purple and the whole sky involved seemed flaming fire, then dying faded out to sudden night. It is impossible to justify by description, it would be impossible for artist to paint the glory of those sunsets.

The dipterists found the nemestrinid *Hirmoneura texana* Ckll. again and also a blood-sucking leptid (*Symphoromyia*) and some fine Syrphidæ and others of interest. Dr. Bequaert and Mr. Knight collected specimens of *Tibicen castanea* Davis and of a variety of *T. cinctifera* Uhler. Amongst moths we found *Ptychoglene phrada* rather abundant, flying by day and visiting flowers. It closely resembles the lampyrid, *Lycus fernandezii* Duges, from the same zone, a specimen of which we found later at Texas Pass. Dr. Wheeler, with the help of the rest of us, listed forty-

three species of ants, representing twenty-four genera. Perhaps the most notable was *Polyergus lucidus*, the shining slave maker, well out of its known range. Several of the party witnessed a raid of this species upon a species of *Formica*. *Mutilla orcus* was common, and the collecting for wasps on the various flowers in the cañon as well as lower down was excellent. The erycinid *Apodemia nais* was abundant in the cañon, and we obtained quite a series; other interesting butterflies were: *Basilarchia arizonensis, Limenitis bredowi, Neonympha rubricata, Thorybes epigona, Kricogonia lysida* and *Terias mexicana*. Among the beetles may be mentioned the cactus longicorn, *Monilema appressum*, a female *Prionus heroicus, Sphænothecas suturalis, Discodon bipunctatum* Schaeffer and the large odd *Erotylus boisduvali*. Some of the tarantula hawks had elegant violaceous wings with white tips, standing in marked contrast to the ordinary red-winged type; these belong to Lucas's species *oblikuerugosa*.

It may be of interest to mention some of the reptiles of this locality. *Sceloporus jarrovii*, an uncommon swift, was associated with the larger, more bristly and much more common *S. clarkii*. Up in the cañon, more or less into the Canadian zone, lives *Gerrhonotus nobilis*, a clumsy creature sometimes called an alligator lizard, contrasting strongly in his slow motions with the swift scurrying lizards of the desert. The common horned toad of the lower slopes is *P. cornutum*, but upon a ridge Needham and the writer found the red head, *P. hernondesi*, which we also found well up in the Catalina Mountains; also up on the mountain Dr. Murry and Ralph Wheeler caught a dog-faced rattler, *Crotalus molossus*. The whip tailed lizard, *Cuemidophorus gularis*, and *Uta ornata* were other lizards observed. One of the most beautiful birds was *Phainopepla nitens*, suggestive of a cedar waxwing in appearance, but not color. A pierid butterfly, probably *P. monuste*, was very abundant near the school.

On leaving the Pinaleno Mountains we stopped awhile at Bonita; found many fine bees sleeping in the flowers of *Cucurbita fœtidissima;* among them males of *Xenoglossa patricia* Ckll. (identified by Dr. Lutz). This bee has very large ocelli and is probably nocturnal or crepuscular.[2]

Dr. Wheeler, who had collected previously in the Huachuca Mountains, came to the conclusion that the forms of the lower slopes of these two ranges are very much alike. I should advise any one wishing to collect at higher levels in these mountains to enter them from Thatcher or Safford on the eastern

[2] Note by Dr. Bequaert.

side. I am informed that pack outfits may be obtained there and that there are two summer camps up in the pines.

West of Willcox we saw some fine mirages, and crossing extensive alkali flats came upon great numbers of several beautiful species of *Cicindela*. That night we camped in Texas Pass in the Dragoon Mountains and reckon our day's stay there as entomologically the best of our entire trip. The scenery is notable for the grotesque rock formations, strongly suggestive of the Garden of the Gods. To start collecting off well Mr. Shannon captured by the cook stove an *Amblychila baroni*, Dr. Wheeler another amongst the rocks, and Dr. Bequaert a third. Determined to be as fortunate I hunted everywhere but without success. Flying about the live oaks we observed males of a magnificent large black and orange cerambycid, *Crioprosopus magnificus* Le Conte, an extremely rare beetle. The whole party turned in and collected them, with the intention of marketing the catch, a nice series, to defray a bit of the expenses of our trip, which were mounting high. Dr. Wheeler called our attention to a foray of *Eciton* (the legionary ant of the tropics). On *Zizia*, or some similar very spiny shrub, innumerable aculeate Hymenoptera of many fine species, incessantly active, held Dr. Bequaert's attention, and mine. On these same bushes a beautiful yellow lampyrid, *Lycostoma loripes*, was inordinately abundant; other lampyrids that we caught were: *L. fulvellus, Lycus fernandezi; Cenopœus palmeri*, a fine large longicorn, also was found, and a portion of the tarantula hawks were of the magnificent violet-winged species *Pepsis obliquerugosa*. At the tent light-trap, amongst other things were two speices of the capsid genus *Sericophanes*, one new to science and since described by Mr. Knight as *S. triangularis*, the other being *S. tarnsversus*. Both species Mr. Knight had also caught on previous nights, the new one at Lordsburg, Bowie and Deming, the other east as far as Gillette. The vertebrate zoologists found *Cnemidophorus gularis*, a whip-tailed lizard, for the last time.

(To be continued.)

PSYCHO-PHYSICAL TESTS OF AVIATORS

By Professor GEORGE M. STRATTON

UNIVERSITY OF CALIFORNIA

THE application of psychology to the problem of discovering special aptitude for flying is one of the interesting developments of the war. All such work in this country has had the benefit of that done by the French. Nepper, the most distinguished of them in this field, is primarily a physiologist, but he is aware that the attention to the physical fitness of the man to be trained as a pilot leaves out of account many important things. His idea has been that a thorough clinical examination gives assurance of excellent sense organs, but it leaves quite undecided whether the future aviator will be able to make proper use of the impressions which these sense organs bring to him. He might have added that such an examination gives assurance that the future aviator will have normal muscles, but gives no assurance that he will be able to make use of these muscles with unusual skill.

Nepper laid stress upon two qualifications which he regarded as central and essential for aviation; namely, coolness and the power to make rapid decisions. The power to make rapid decisions he felt could be tested by means of the standard laboratory experiments in "personal equation," or what is more commonly known among us as reaction time; that is, the time which it takes a person to respond by a movement—perhaps of the finger—to some signal. Such signals Nepper gave in the regions of sight, of hearing and of touch, measuring the time of the person's response by electric keys connected with a delicate chronoscope. Having taken a number of such measurements in each of these three senses, he counted it against the man if his reaction time either was too slow or was too irregular. And the person was too slow for him if the average time of his reaction for sight was more than .01 of a second slower than the average time which he found among those he examined, such average time being for sight, .193 sec., for hearing .144 sec., and for touch .142 sec. He also set a narrow limit of irregularity which he permitted in the man's reactions, and if the person was more irregular than this, he regarded it as an indication that the man was unsuitable for training as a flyer.

Coolness Nepper tested by delicate apparatus familiar to all psychologists and physiologists, which gives a written record of one's breathing, of the changes of volume of blood in his finger, and of the steadiness with which it is possible for him to hold his hand, these records being obtained from the aviator in the first place under comparatively normal conditions, which were in due time suddenly changed by giving some violent form of surprise, either by a flash of light, or by cold water, or by a blank shot from a pistol near the man. On the basis of these two forms of experiment he classified his candidates into good and poor, and rejected those whom he regarded as unsuited for the work of aviation.

The Italians also during the great war have used psycho-physical methods in the selection of aviators, the two men whose names have come most prominently in this work to us being Gemelli and Gradenigo. They too made use of the reaction-time experiment and of the test of emotional steadiness, much after the French fashion, and yet with modifications. An interesting enlargement of procedure on their part was by means of what is known as a "Carlinga," which reproduced in some respects the cockpit of an airplane and could be moved in various directions. The candidate blindfolded was required to indicate the vertical after he had been tilted from the vertical; and again, without being blindfolded, was required to respond quickly by means of his "joy stick" to some sudden tilt of the machine. His value as a future aviator was estimated in part by the character of his responses under these conditions.

The work in America, as was said, has had the benefit of this work on foreign soil. With us, the research, beginning among civilian scientists, was in due season taken over by the Air Service of the Army and more particularly in the later months of the war by the Medical Research Laboratory of the Air Service at Mineola. In order to understand more fully the conditions under which the work was planned, it may be of interest to tell briefly the character of the examination of aviators before any psycho-physical features were introduced.

The candidate appeared before some one of the many Aviation Examining Boards established throughout the country, and his examination by the board took two interestingly different directions. The candidate was given in the first place a most careful physical and medical examination by medical officers in the army and he was also given what was designated as a professional and mental examination by one or more officers who were not in the Medical Corps. This latter examination

was based upon the candidate's carefully written answers to several pages of questions that were put to him with regard to his family history, his education, his business experience, his athletic interest and training, the character of the responsibilities placed upon him in civil life, the organizations to which he belonged, and his military experience. He had also to furnish letters testimonial from persons who knew him well, and credentials of his schooling. Of particular importance was the personal interview, when the applicant faced his military examiners and was required to clarify or supplement the facts given in the ways just described. Thus by a direct personal judgment assisted by various means, it was decided whether the man should go into training or should be courteously and with due appreciation told "No."

The method is on the whole an excellent one, though any one who has had experience as an officer upon such a board knows how fallible a judgment often issues from the professional and mental side of the board's examination. It is unquestionably true that many an applicant gives far better promise than his later performances fulfill, and, on the other hand, men are thrown out by such a method who would have made successful aviators.

The purpose of proposing psycho-physical tests in the Air Service was not to do away with any part of the several examinations here described, but rather to supplement these examinations and reduce the probability of error in them. And in particular the research with which this paper is concerned aimed to discover whether certain and particular tests that might be proposed would actually assist appreciably the examinations already established in the Aviation Examining Boards. The method was not to adopt tests out of hand on the assumption that they must of necessity distinguish promising from unpromising candidates. Rather the investigation aimed to put the tests to trial and to find out whether they actually gave evidence of worth. Until they could give scientific evidence of their value, that value was regarded as wholly problematic.

The tests which were subjected to investigation were in part similar to those used by Nepper and Gradenigo; but, for the sake of wider exploration, many other tests were brought to trial. Every investigator is in debt to many others, and especially is this true in the present case. Professor Brown and his assistants at the University of California, Professor Thorndike, of Columbia University, Professor Henmon, of the

University of Wisconsin, and Doctor Burtt, of Harvard University, made possible by their scientific judgment the research here reported. Nor within the Army itself was the work possible save by a hearty personal cooperation of a great number of officers and men, in Washington, in Mineola, and at San Diego. Everywhere in the army such work as this found something that could not be had by force of mere authority and orders.

Besides reaction time and emotional stability, aviators were tested as to their power rapidly to learn to form several complicated and untried combinations of muscular movements not unlike those which an aviator has to learn, the idea being that in this way the least skillful persons might be eliminated. Other tests were concerned with a careful recording and measuring of the success with which a person could stand motionless with eyes open and with eyes closed, indicating general and constant control over the muscles of his body as a whole. He also had to show evidence of the fineness with which he could perceive gradual departures of his entire body from the perpendicular brought about by a mechanism of screws and levers, the test being aimed at his sensitivity, his power to perceive, rather than to control, since it might well be asked whether a nicety of perception of the position of the body is an important factor in guiding the aviator as he restores his airplane to its proper balance in the air. And, since the landing of the airplane is one of the difficult parts of the aviator's early task and requires judgment as well as careful response and control as he approaches the ground swiftly with his ship, he was tested as to his power to continue in imagination certain fragmentary curves that were given him; for his skill in landing might well require him to anticipate where his present course at any moment would, if continued, carry him and how he must needs alter it to make it suitable in angle, speed and place. A simple test of dexterity was also used; the candidate was required to balance one of a graded series of rods vertically upon his finger for a stated time to see how short a rod he could balance; and his success or failure in this was accurately measured.

Even after findings from such tests had been obtained, they still were regarded as subject to check and suspicion. The tests were repeated with different groups of aviators at the same field, and under the direction of different officer-scientists at different fields, in order to reduce the danger that the particular findings might be the result of chance or of some special

interest or error or suggestion of those in charge of the experiments. And as an essential element in determining the value of any test, it was necessary to have the best judgment of the army officers who were actually in charge of the aviators' training in flying. For the psychologist did not assume that he could as yet estimate by his tests the fitness of any person for flying. He simply wished to discover whether, as a matter of fact, there was any parallel between the degree of success with which a person could pass a given psycho-physical test and that person's peculiar skill as an aviator; and this skill must be judged not by a psychologist, but by one practically versed in flying, himself a flyer and a trainer of flyers. A possible parallel between success in aviation and success in passing the psycho-physical tests would constitute what is known technically as a "correlation," to be indicated by a mathematical expression known as the "coefficient of correlation."

The outcome of the experiments was that, as a matter of fact, these tests all showed a relatively low correlation with flying ability, and yet, in some of the tests, there actually was invariably a correlation of respectable amount. And this made it clear that the test itself might, with proper precautions and supplementing, be used with some degree of reliability to assist in the work of selection.

The tests which under this stern trial proved to be of value were those on the perception of gradual tilt, on the power to stand steadily, as judged by the record which a man makes when a writing point attached to his head moves over a smoked surface, on his power quickly to discriminate between a sudden jerk of his body to the right or to the left, particularly when this is combined with his reaction time to a visual signal and to an auditory signal, and on the steadiness of his hand when a pistol shot is fired behind his back. The tests which did not scientifically justify themselves were those upon a person's power to learn certain complicated combinations of movement of hand and foot, on the power to continue in imagination a fragment of a curve presented to him in model, and on dexterity. This latter test was disapproved not so much because it arrived at nothing which could be connected statistically with flying ability, as that it could so largely be influenced by practise, and practise would be invited if the test were introduced as a regular part of a board's examination, when the candidates would soon know beforehand that they would be tested on this feat of dexterity.

The research may therefore be regarded as having had its measure of success. Tests were actually found by which it was possible to give a more assured judgment than was possible by credentials or by personal interview that the candidate could learn to use with skill the sound and normal body which the medical examination gave assurance that he possessed. But it will perhaps not be needless to repeat that in the writer's judgment such tests are not, nor do they promise to become, a substitute, but only an assistance to the other and standard means of estimating a candidate's ability.

The experiments bring home to one the exceeding complexity of the flyer's ability. His power to attain success in his hazardous and delicate work evidently is not due to any one factor in his psycho-physical constitution, nor to any small group of factors, but rather to a happy constellation of many factors, of which each counts only in a limited way.

A French aviator who examined with some care and moderate approval the apparatus which has been described, expressed appreciation of the work, but expressed also his conviction that such tests did not touch the central fitness of the aviator, the "heart" of the man, meaning, no doubt, the courage, the temperament, the spirit which he would show only in the midst of danger or of crushing fatigue. Such a reservation in judgment the writer feels is not to be despised even by those enthusiastic over instrumental means of discovering special ability. Such doubts, however, should not discredit the laboratory means, but rather should keep them in their place. In so difficult a matter as that of determining special ability to fly, all agencies and aids are needed. Any one means is fallible; but when all good means are joined, there is prospect of far greater success, of far less error and failure. Especially would it be unwise to say that we have already exhausted the possibilities which lie in psycho-physical tests. Judging by the past, it seems likely that a research of this kind has merely come to the threshold of its opportunity and that it will with time and intelligence and ardor enter a region of fruitful work of which we have now but a faint idea.

DELUSION, MASS SUGGESTION, AND THE WAR: A DREAM AND THE AWAKENING

By Professor JOSEPH JASTROW
UNIVERSITY OF WISCONSIN

THE classification of delusions as innocent and dangerous does not commend itself to the scientific student; to a practical-minded society, exposed to the contagion of error, the distinction is supreme. Circle-squarers, discoverers of perpetual motion, solvers of the riddle of the universe are nuisances only to the patent-office, to philanthropists, and to professors. But couple the same order of mental twist with a grudge, give it a setting in political conflict, and you have the motive that made martyrs of three Presidents. The erratic masses have the same complexion as the erratic individual; but the collective menace is indefinitely more formidable. Yet popular delusions may be fairly innocent. When the stolid Dutch burghers of the seventeenth century spent half a fortune for a rare tulip-bulb, or the staid investors of France and England in the eighteenth century fought for the privilege of subscribing to the "Mississippi Scheme" and other speculative "bubbles," or the corresponding classes of New York and Boston fell for the "Perkin's tractors" (see Oliver Wendell Holmes), or put blue glass in their windows to absorb the health radiations before the days of absent treatment, the fad had no more serious aspect than the loss of money, of energy, and the momentary depreciation of the currency of sanity. When a powerful nation loses its reason on the subject of war, the world is aflame; and the allied fire-departments of the sane nations are summoned to extinguish the conflagration.

The stages of the made-in-Germany war may be traced psychologically in terms of delusion and mass-suggestion. The mental munitions were as essential as those for rifles and shells. Like the material preparedness, the campaign of delusion was inaugurated decades ago. An early form of the delusion was that of encirclement. The German people were encouraged to believe that they were surrounded by envious and increasingly aggressive nations. The French motive was revenge; the English greed; Russia stood for the Slavic peril. Gradually the

suggestion took hold that war was inevitable; the "*Tag*" was on the calendar. Once endured, the notion was cherished, then embraced. The delusion was incorporated in desire, enhanced by ambition, and justified by a flattered self-esteem. The finger of destiny pointed to the German Empire; the German was the superior race; German Kultur alone could redeem mankind. Every delusion, every subterfuge, every evasion is motivated by desire—as no one has more subtly demonstrated than the keen Austrian alienist, Dr. Freud—but in its expression meets with resistances. These must be overcome. The moral resistance goes out against an offensive war; defense is sanctioned, becomes a patriotic virtue. Hence the further elaboration of the delusion—the fiction of a preventive war. The transfer of guilt to others is essential to the self-esteem of delusion. Since the enemy is preparing to attack, he can be met only by an anticipating offensive. Hence the war, however it came, was "the war that is thrust upon us." That phrase is the nub of the aberration, repeated to nauseating insincerity, but clung to to the last. It remained set as the keystone of the delusion; with that loosened or detached, the arch must crumble.

War is a complex enterprise; the system of delusion that supports it is equally so. The soil in which delusion is to grow must be well prepared. The cultivating process is at once positive and negative. The mind must be made docile and submissive; it must see and see intensely what it is directed to see, and nothing else. The blinders must not be worn on the outside where they might be removed; they must be grafted on the seeing organ itself, and induce a mental blindness. Obedience to orders must be made a national habit, and *Verboten* signs plentifully distributed and rigidly heeded. Habits of thought must be censored; the press is to print only what the Minister of Delusion issues. The people must be fed on figments in generous rations, and substitutes for truth circulated at all hazards. To within three days of the final smash, all enemy attacks were uniformly repulsed in the German reports, all retirements were voluntary and to carefully prepared positions. The Marne was an unknown river in Germany; victories were heralded in megaphonic tones, and promises were accepted when victories failed.

The technique of denial and that of justification were carried on side by side; the deluded mind is not sensitive to inconsistency. Belgian civilians were snipers; the stories of Hun cruelties were fabricated in London. The German army remained the finest school of morality anywhere in session; Ger-

man Kultur could not be guilty of the reported violations; and whatever Germans did was right, as the State could do no wrong. The more tender-minded German citizens, retaining reserves of moral resistance, were narcotized by the denial; the tough-minded who had abandoned them (and in the sacrifice, if such it was, could be comforted by the authority of Nietzsche) were stiffened by the official sanctification. So vast a delusion must reach and enthrall all sorts and conditions of men. The *Massensuggestion*—which is the German term for the mote in their neighbor's eye and is not applied to the beam in their own—was as huge and as highly organized as the German army itself; recruits of delusion can not be conscripted, but they enlist in equal numbers by the contagion of suggestion. The machinery of delusion must be kept running, and all the reserves of the psychological armament drawn upon. There was the campaign of hate, as well as the campaign of superiority, and the campaign of Pan-German ambition, the whole culminating in a gigantic, relentless megalomania. Follow the trail of the hate, and it leads to the bitterest disappointment. France was expected to resist; that England should shatter the glorious plan at the outset by keeping her pledge to Belgium made all Englishmen hypocrites, and the German's daily prayer: "*Gott strafe England!*" For that is the way of delusions among the insane in asylums as in nations at large, fixing the object of suspicion or wrath upon the frustrator of desire.

It is true to the psychology of delusion that it should aspire to the intensive force of great emotional exaltation by which the heroic deeds of individuals and the collective enthusiasms of masses have reached the high moments of human endeavor. A mystic, a religious fervor attaches to them, retaining in the one instance and losing in the other the fine distinction that divides the sublime from the ridiculous. Exaggeration and self-absorption inhere in both. The partnership of the Kaiser and Gott—now apparently dissolved—is more a symptom than a pose. The imperial exaltation and autocratic omnipotence of a sacrosanct emblem of power is a popular asset to the spread of a dazzling cause. The same self-deluded and self-exalted mood of prerogative extends to the lesser stars of the constellation; and the wretched Zabern affair thrilled far more generally than it outraged the German sense of propriety.

Out of it all grew the national habit of delusion, the refusal on the part of those directing, the inability in those who succumbed to the delusion to see things as they are. Figments, fictions, vain imaginings, blind denials, perverted excuses, crude

suspicion, unreason rampant, all sanity forsaken in a psychic saturnalia of abandonment: such is the picture of *Mania Teutonica!* Such is its contribution to the history of mass-suggestion; such is the world war considered not as a military conflict of nations, but as the direst mental epidemic, the most devastating trench-fever that has ever swept over the minds of men to their undoing.

All delusions reflect the expressions and the circumstances of their time. In older days deluded patients heard divine voices in the air; now the inspired messages come through an invisible telephone. Formerly the victims writhed under the torture of the minions of Satan; now they suffer through "malicious animal magnetism" and mental vibrations. The political aspect of the great German delusion that precipitated the world-war and maintained it for four years in all its terror, all its running amuck among the shrines and sanctuaries of civilization, wears the garb of the twentieth century. Since liberty is the political concept of the generation, the Germans maintained the delusion that they were free. They accepted the strait-jacket as the uniform of patriotic discipline, and the padded cell as a token of solicitous paternalism. They accepted the tether of their permitted excursions as the limit of wise desire, and the goose-step as an improvement in human locomotion. German *Freiheit*, like German *Treue*, was an ancient quality; its venerability ensured its permanence, let the facts be what they may. The license of other lands inhabited by a degenerate and mercenary folk was an unenviable example; the invincible German army was the triumphant reward of discipline, and the industrial conquests—the only real structure in their astigmatic *Realpolitik*—a comfortable second prize for the dull days of peace. Through the network of delusion runs the double strand of concern for the values regarded by the rest of mankind, and the camouflaged thread that loosens every mesh. Germany professes peace while she plots war; Germany is indignant that neutrals should have opinions denouncing Teutonic ways, and places its arch-spies in the embassies of countries too generous to be unduly suspicious.

Somewhere in the moving German theater of war hangs the curtain that separates the performers on the stage from the audience: the responsible actors initiated into the plot and the deluded people who accept the drama as real. Unmistakable is the responsibility of the intellectuals, and pitiable the treason to their trust. *Lehrfreiheit und Lernfreiheit!* another slogan of delusion! Again the two camps of denial and of justification.

The ninety-three professors, thirty-five of them men of science, professing loyalty to the principles of proof, yet protesting seven times over: "*It is not true that*" of violations in Belgium of which they could not have the slightest knowledge, and which have been proved seven times worse than first reported; quite as many of the learned guild justifying by shameful jugglery the crassest fallacies and grossest idols of the mob. Can one fail to suspect that they owe the high positions which they occupy to the truculent qualities revealed under the stress of a war-delusion? The military and political leaders may have heavier sins to bear, but they have not added prostitution to their crimes. What wonder that with such perversity among respected leaders, the baneful suggestion could spread without check among the well-drilled masses! For the overwhelming fact, once we have partially recovered from the super-Satanic enormity of the plot, is the eager acceptance of such a devastating, demoralizing, dementalizing delusion by a supposedly enlightened people. It is as true of nations as of offending individuals, that those whom the gods would destroy, they first make mad.

Yet the interest of the psychologist is not in judgment as denunciation, but as understanding. Now that we can see in close retrospect the movement of events steadily and see them whole, we turn with admiration to those whose insight was prompter and truer than ours. Our lack of preparedness to meet the military situation testified to our creditable incredulity that such things could be; our lack of understanding of the stages of revelation requires to be more charitably interpreted to be so regarded. Of all the readers of the handwriting on the wall—now that Babylon has fallen—none is more deserving of the honor that is denied to prophets in their own lands and beyond them, than Professor Otfried Nippold of the University of Berne. A specialist in international law, a supporter of the Hague Conferences, the son of a German professor, a close student of German tendencies, his warning issued in 1913 in his "German Chauvinism" remained largely unheeded, despite the fact that the volume contains Germany's own evidence of hope and intention, of confident defiance and overweening self-assertion. It is to Professor Nippold's credit that for five years he has interpreted the German situation as a vain dream, and has consistently predicted the awakening and the *Katzenjammer* of many a day after. He has ever had confidence in the existence of another mind in Germany, a minority, small but not insignificant, the true *Realpolitiker*, ready to see things as

they are—as other sane people see them. Deeply disappointed in the renegade performances of the Social-Democratic leaders, he yet hoped against hope that the saving remnant in Sodom would appear. As a Swiss neutral, he protested against the right of a formal neutrality to deprive him of free speech. He warned the German Swiss of the treachery of the propaganda of Berlin, and, like President Wilson, he held it to be the duty of all true friends of Germany to save the German people from their arch enemies, the German autocratic government. And yet, in February, 1918, bowing to the despairing truth as he saw it, he wrote:

> The people has no voice, and indeed it has no desire to make its voice seriously heard; it is content if it can but shout "Hurrah!" with Hindenburg. The German Revolution is still remote. The German people has not yet awakened. And the German Reichstag is the personification of modesty; it believes everything that the Government considers it desirable that it should believe.

With a stronger faith in the psychological uniformity of human emotion, he would have anticipated that the violence of the reaction would be proportional to the intensity of the disillusionment. The vain dream of Teutonic mania, the terrible nightmare of the rest of the world is over; the awakening has come. The road to recovery is long and difficult, but it is the clearly charted road of sanity. The lesson of the war is not alone the triumph of right, but the supremacy of sanity, the enthronement of right thinking as the safeguard of right action. The lesson of Germany, as the fallen assailant of right thinking and right action, is a demonstration on a national scale of the psychology of delusion. Delusion and deception, the one inward, the other outward in its operation, hold the psychological key to the frightful drama that was played on the political stage. The technique of the self-delusion with its sense of superiority, disdain of others, blindness of mind toward the obvious and the real, calls to its aid the technique of the deception of others by treachery, intrigue and plot. The common ground is the domain of lying, and the brutal products of cruelty, hatred and the abandonment of restraint. It is the war as a psychological phenomenon that is enlightening, the costly demonstration that the minds of men are the arbiters of their fate. The delusion that begins as a mockery ends as a snare.

TROPICAL VERSUS ARCTIC EXPLORATION

By the late THEODORE DE BOOY[1]
YONKERS, N. Y.

WE wonder if the average reader has ever realized that tropical exploration spells something else besides sitting on a hotel veranda, surrounded by dusky servitors whose sole object in life is the carrying of iced drinks which are usually said to be provided with the proverbial "stick" and sometimes even with the "big stick"? Compared to what the general ideas are about trips to the polar regions, it must be admitted that one feels more favorably inclined towards a visit to the tropics than towards a voyage to the arctic seas. Let us see how the two journeys compare.

One leaves New York, let us say, for a voyage to the arctic regions. Knowing full well that one will find but little in the way of food after leaving the last Eskimo outpost, a stock of edibles is laid in that embraces the products of the Seven Seas. True, most of this stock is in canned form and not comparable to the delicacy of one's daily menu. But one has the means of transporting the stuff, first on the vessel that is used for the exploration and afterwards on the dog sleds that are certain to be employed on the venture. The glamor that goes with all arctic voyages does not fail to attach itself to the undertaking. In consequence, one is heralded by the newspapers, fêted by the scientific societies and farewelled by one's friends. This incident publicity also means that but little trouble is experienced, in normal times, to secure the necessary funds for the expedition.

The reverse of the above is true for the outfitting of a tropical undertaking. Funds are hard to secure. Does not the jungle provide all that is necessary towards a happy existence? Else why the breadfruit and the banana? And does not the coco palm provide the material for the building of houses, the making of hats, the manufacturing of mats and clothing and at the same time provide food in varied form? The tropical explorer asks for funds only in order to spend more time on the hotel veranda and, once in the bush, needs naught beyond the abundant resources of nature! As a result, with but few exceptions, the tropical expedition is all too scantily furnished with funds. Why trouble with clothing? The natives dispense

[1] The author of this article, distinguished for his explorations in tropical countries, died from influenza while it was passing through the press.—EDITOR.

with it. Why carry instruments or medicines? The tropical climate makes the latter unnecessary and, as for the instruments, why trouble to take observations when *per se* the tropical explorer is discredited before even leaving his native shores?

And now, let us see what happens when the field of exploration is actually reached. I am not qualified to speak of arctic conditions from personal experience, but any reader of arctic literature will agree with me that the situation as I shall show it is more or less in accord with general experiences. As a parallel, I shall show what the tropical equivalents are and leave the reader to decide upon the verdict.

The arctic explorer leaves his base. He is generally accompanied by a goodly party which makes traveling all the jollier. The provisions, be they ample or be they scant, are packed on sleds, drawn by trusty dogs. Generally the trusty dogs are too trusting, as they not infrequently wind up their useful career as nourishment for the explorers. Progress over the ice is fairly rapid and at times easy, especially when the explorers are riding on the sleds. One can see in all directions. There are no hostile inhabitants to contest the right to visit the region. It is cold, but the special clothes that are worn go far towards alleviating this hardship. Camp is made at night, after covering perhaps as much as twenty or more miles, a satisfactory day's progress. No time is lost in setting up the small tents and in preparing the food with liquid fuel. Outside of the cold, one is quite content.

The tropical explorer leaves his base. He usually travels alone or at the best with but one companion. No matter who the chief of the party is, he will usually quarrel with his associates before the expedition has progressed very far. This is due not to a mean streak in his make-up, but to the irritating effect of the climate and the mosquitoes. Naught but two saints —and these are scarce upon the earth—would travel a hundred miles through the tropical bush without having at least one violent quarrel. On leaving the base, certain provisions have to be taken along. The tropical forest is not nearly so generous with its gifts as one hears mentioned. The provisions that are taken weigh a great deal and have to be transported on the backs of the carriers. One is lucky to obtain sufficient carriers. Generally, the demand is far greater than the supply, so that, in the end, the amount of food that goes with the explorers is pitifully small. However, the tropical explorer is by nature optimistic and generally risks the chance of being unable to obtain game during his stay in the jungle. Of the food carried, at least fifty per cent. will spoil on the trip. This is mostly due

to the intense humidity that is experienced. The daily progress made depends entirely upon the nature of the country. Sometimes it is as much as ten miles per day and often it is as little as four miles per day. Under the most unfavorable circumstances it means a slow, laborious cutting through the dense underbrush which is fatiguing and trying on the nerves. The thorns, with which so many bushes are plentifully endowed, do not fail to exact a bloody toll from the explorer. The thousand and one insect varieties lose no time to apply for their quota of the traveler's blood. Again, hostile Indians may be met with, and these may carry out what the insects tried to do, and put a final stop to progress in the desired direction. It is at last decided to make camp at night. Some leaves are cut and a temporary shelter is hastily erected. The more hastily this is done, the surer it is to rain that very night. By dusk, one begins to consider cooking a meal. Despite all the fallen giants of the forest, there is nothing harder to find than dry firewood in the tropics. At last a smouldering fire, with much smoke, has been created. Just about then, the mosquito outposts have spread the news to their far-off brethren that a newcomer is in the forest.

The arctic explorer travels on. One day's progress is not much different from another. Sometimes it snows and sometimes it is clear. Always he can see the road ahead. His provisions get low after a while, but he is still able to press on with comparatively little fatigue. At last the goal is fairly near. If it is reached and he returns in safety, a new discovery is hailed by press and public. If he fails, the return voyage provides him with ample leisure to explain, ingenuously, wherein the failure lay and how it was caused. The return of the arctic explorer is hailed with joy and he has even less difficulty than before in obtaining funds for a new expedition. Should failure mean death, his widow is fêted, honored and made to publish reminiscences of her husband. As for the lonely corpse upon the ice floe, it is generally discovered in later years. Death in the arctic means death from cold and starvation. I can not believe that such a death is hard.

The tropical explorer travels on. There is a startling variety in the experiences of each day. Sometimes he travels through the dense underbrush, combating with nature at every step, cutting down the very effective barriers of jungle which seem to defy his attempts at exploring the mysteries that lie beyond. Again, the trail leads over forbidding mountains. On the summits of these a cold is experienced that eclipses any cold suffered in the arctic. The explorer lacks all means to pro-

tect himself against these climatic changes. After a while he strikes a swampy region where the dreaded miasma covers the landscape with a mantle of death. Wild animals, wild Indians and wilder insects conspire against the traveler's happiness and peace of mind. Provisions get low. The tortured explorer, racked by fever, covered with insect bites and sores, enfeebled from lack of food, continues only because he knows that he is nearer to his goal than to his base. And if he reaches his goal? The few that hear of his success must needs consult a map to learn of his achievement. His friends regard his claims to recognition with scant concern and are too much inclined to dwell upon the delights of the tropics to take the narrative of his hardships seriously. The explorer is forgotten before he was ever remembered. He is forced to return to his tropics where nature at least does not belittle his attempts at solving the mysteries of the Beyond, but appears to feel that the great obstacles she places in his way serve but to heighten his achievement. And if the explorer fails to reach his goal? It would not be well to dwell upon the nature of his death. May be some kindly Indian arrow made it short. May be he lingered long, deserted by his carriers, tortured by insects, with fever visions that accentuated his agony, helpless to proceed, helpless even to do more than wish for a speedy ending. So have the tropics taken toll, year after year, century after century.

And now for the results. The arctic, practically all explored, and we have arrived at the realization that, while the scientific results of the expeditions are beyond price, the practical results have yet to be demonstrated. The tropics, partially explored, and the world has been enriched with new lands, new minerals, new drugs and a wider outlook. The pioneer, the explorer, has been forgotten, but the settled areas that resulted directly from his labors and his sufferings are monuments more impressive than those an ungrateful public failed to erect.

It must not be thought that these lines are in any way intended to slight the pretensions of arctic explorers. The work done by these intrepid travelers is beyond all praise. But so is the work that is carried out by the tropical explorer and this fact appears to be so seldom recognized, more is the pity! For the first, the medals, the glamor and the glory; for the second, the obscure position in the scheme of things in general, or, at the best, the self-knowledge of a task well done. And at the worst—the bleaching bones under the noon-day sun, seen only by the jaguars and the parrots, a warning, and at the same time, an attraction, to others who have the same longing for the tropical mysteries.

THE OLD INTERNATIONALISM AND THE NEW LEAGUE OF NATIONS

By C. C. ECKHARDT, Ph.D.

ASSISTANT PROFESSOR OF HISTORY, UNIVERSITY OF COLORADO

IN drawing up the provisional draft of the Covenant of the League of Nations the commission has recommended that all international institutions existing before 1914 be utilized in the prospective international state.

> Article XXII. The high contracting parties agree to place under the control of the league all international bureaus already established by general treaties if the parties to such treaties consent. Fundamentally they agree that all such international bureaus to be constituted in future shall be placed under the control of the league.

It is the purpose of this article to give an account of the various bureaus and organizations that may be taken over by the league.

Before the World War broke there was a surprising amount of international activity carried on by various groups of states. There were sixty odd official organizations cooperating to facilitate and improve methods of communication, to promote commerce, to carry on international police and sanitation work, to secure and disseminate scientific data, and to perform various social, economic and political matters of common interest. Some of these activities were carried on by permanent bureaus, commissions and institutes, and it is these standing organizations that are to be taken over by the league of nations provided the signatory powers in each case agree to such a transfer.

Foremost among international organizations, though very quiet in its workings, is the Universal Postal Union, in existence since 1874. All the nations of the world are members; periodical congresses and conferences are held to draw up regulations for the handling of the mail of the world. The Union established a bureau in Berne for the purpose of collecting and publishing information and statistics concerning the work of the Union and to investigate and make known the needs of the Union. The expenses of this bureau are borne by the various powers in accordance with a certain scheme, each nation contributing its share in proportion to its size and the amount of service it gets from the Postal Union. This system has evidently worked well, for in article five of the Covenant of the League of Nations it is provided that "The expenses of the

international secretariat shall be borne by the states . . . in accordance with the apportionment of the expenses of the international bureau of the Universal Postal Union." The arrangement is this: The countries of the Union are divided into seven classes, each contributing in proportion to a certain number of units. The first class contributes 25 units, the second 20, the third 15, the fourth 10, the fifth 5, the sixth 3, the seventh 1 unit. The states of the first class contribute twenty-five times as much as the states in the seventh class; the states of the second class twenty times as much and so on.[1] The budget of the Union has been surprisingly small. In 1874 it was fixed at $15,000; in 1878 it was increased to $20,000; in 1891 it was raised to $25,000, though the expenditures have always been less than this last amount.

There are three other organizations with permanent bureaus to take charge of various aspects of means of communication. Since 1865 there has been an International Telegraph Bureau supported by all the European states and some countries in South America, Asia and Africa. Since 1908 this bureau has a special division that issues regulations and information concerning wireless telegraphy. Eleven of the continental coun-

[1] The countries of the Union are classified as follows:

First class: Germany, Austria, United States of America, France, Great Britain, Hungary, British India, Commonwealth of Australia, Canada, the British Colonies and Protectorates of South Africa, and the whole of the other British Colonies and Protectorates, Italy, Japan, Russia, Turkey.

Second class: Spain.

Third class: Belgium, Brazil, Egypt, Netherlands, Roumania, Sweden, Switzerland, Algeria, French Colonies and Protectorates in Indo-China, and the whole of the other French Colonies, the whole of the insular possessions of the United States of America, Dutch East Indies.

Fourth class: Denmark, Norway, Portugal, Portuguese Colonies in Africa, the whole of the other Portuguese Colonies.

Fifth class: Argentine Republic, Bosnia-Herzegovina, Bulgaria, Chile, Colombia, Greece, Mexico, Peru, Servia, Tunis.

Sixth class: Bolivia, Costa Rica, Cuba, Dominican Republic, Ecuador, Guatemala, Hayti, Republic of Honduras, Luxemburg, Republic of Nicaragua, Republic of Panama, Paraguay, Persia, Republic of Salvador, Kingdom of Siam, Uruguay, Venezuela, German Protectorates in Africa, German Protectorates in Africa, German Protectorates in Asia and Australasia, Danish Colonies, Colony of Curaçao (or Dutch West Indies), Colony of Surinam (or Dutch Guiana).

Seventh class: Congo Free State, Corea, Crete, Spanish establishments in the Gulf of Guinea, the whole of the Italian Colonies, Liberia, Montenegro.

"United States Statutes at Large," Vol. 35, Part II., 60th congress, 1907–1909, pp. 1730–1732. Universal Postal Union, Universal Postal Convention, signed at Rome, May 26, 1906.

tries of Europe have since 1893 maintained a bureau that oversees the execution of various agreements concerning international freight service. Through this organization it is possible to send freight from one country to another without unloading at national frontiers, and the publication of railroad tariffs enables shippers to ascertain freight rates and the changes made in those rates from time to time. One of the most successful phases of international cooperation has been the work of the International Danube Commission, created by the Congress of Paris in 1856 at the close of the Crimean War. This commission is composed of representatives of England, France, Germany, Austria, Russia, Italy, Turkey, Serbia and Roumania; it has made the lower end of the Danube navigable by dredging channels and keeping them open; the expenses incidental to these activities have been met by the collection of tolls.

There have been three bureaus to handle various international commercial matters. Since 1890 all European states except Switzerland, Luxemburg and Montenegro have maintained a bureau at Brussels for the publication of tariff rates. Through these publications the merchants and manufacturers of these countries are kept constantly informed concerning the import and export duties of the countries of the union. In 1902 all of the states of Europe that raise sugar signed a treaty regulating the production of sugar in each country so there would be no oversupply or unnecessary competition between the countries. A permanent bureau, stationed at Brussels, is composed of the representatives of each of these European states and Peru; the bureau sees to it that the existing agreements are executed and also collects data that must be considered by the conventions that are held periodically to formulate new regulations. Most of the states of Europe, the United States and some Latin American states maintain the international bureau of metric weights and measures at Sèvres, France. This bureau has charge of the original metric weights and measures, such as the meter, the gram, the liter; it is here that can be found the original platinum rod or stick that is one meter long at the temperature of melting ice. It is also the purpose of this union to perfect the metric system and to secure its universal adoption in the interest of science and commerce.

On three occasions the European powers have created international commissions to administer the financial affairs of debtor nations, in order to ensure that an adequate part of the revenue would go towards paying the interest on the public debt. In 1878 was created the international commission for the administration of the Ottoman debt; in 1880 the powers

organized the international commission for the supervision of the financial administration of Egypt. After Greece was defeated in her war with Turkey in 1897 she had to pay Turkey an indemnity of $20,000,000; to see that this was paid the powers established the international financial commission at Athens. It is not at all unlikely that some form of commission will be created by the Peace Congress to administer the finances of Germany so she may meet the financial obligations imposed by the indemnity that is sure to be exacted from her.

For the international administration of justice a number of permanent organizations have been created. Best known of all these, of course, is the Hague Tribunal, established in 1899 by the first Hague Conference, and given an enlargement of powers by the second Hague Conference in 1907. This tribunal or permanent court of international arbitration is composed of four representatives of each of the contracting nations, and in case of disputes being submitted, the disputants select whom they please from these members of the court. Since its organization this court has adjudicated fifteen international disputes. There is a permanent administrative council that looks after the affairs of the court; it is composed of the accredited diplomatic representatives of the contracting powers at the Hague. An administrative bureau exists also; its duty is to keep the records and do the secretarial work of the tribunal. It is not clear that the Hague Court will be taken over by the league of nations. Article XV. of the Covenant states: "The executive council shall formulate plans for the establishment of a permanent court of international justice, and this court shall, when established, be competent to hear and determine any matter which parties recognize as suitable for submission to it for arbitration under the foregoing article." There is no good reason for not taking over the Hague Court and modifying it as necessary. Of course the Hague Court as constituted before 1914 was made up of representatives of forty-four nations, and thus far only fourteen nations are participating in the discussions of the league of nations. Much will depend on the number of the nations entering the league and on whether Germany and her allies will seek and be granted admission to the league.

In 1907 was formed the Central American Arbitration Union, with a court at Cartago in Costa Rica. This court has settled three disputes. If the Monroe Doctrine and Pan-American interests are recognized by the Peace Congress, as will presumably be the case, the continued existence of the Arbitration Union of the American Republics will be assured. This

organization has been in existence since 1892 and settles all disputes arising out of money matters. It includes all American republics except Venezuela, Brazil and Panama.

Before 1914 there existed three international organizations for the purpose of protecting intellectual and literary property. Since 1885 the European nations, the United States and other countries have maintained an organization at Berne to protect the owners of patent rights, copyrights, trademarks, trade names, and to prevent the false labeling of goods as to their origin. There has been a European organization with its bureau at Berne to protect artists, authors and composers against pirating and the violation of international copyright laws. The Pan-American Union has a similar organization with two bureaus, at Havana and Rio de Janeiro.

Various groups of powers have maintained organizations and bureaus for police and sanitation purposes such as the following: To prevent illegal trade in alcoholic liquors in the North Sea, to prevent the sale of alcoholic liquors to African natives, to prevent the spread of cholera and other contagious diseases, to suppress the African slave trade, to suppress the white slave trade.

Most of the European nations and some others have cooperated in scientific investigations. There are bureaus for carrying on geodetic surveys, for studying the causes of earthquakes and making seismological observations at stations in all parts of the world, and for taking deep sea measurements. The International Institute of Agriculture at Rome has existed since 1905 for the purpose of compiling statistics concerning agriculture in all countries. The bureau of the American Republics collects and publishes information concerning the political and economic conditions in all countries in the Pan-American Union.

The foregoing shows that before the Great War there were many international organizations and much cooperation among nations. It is gratifying to see that the Covenant of the League of Nations provides for the assumption of all of these activities wherever that can be arranged by the League. It is to be hoped that all or most of these activities will be taken over by the league and that the international life that existed before 1914 will be merged into a larger and deeper world organization that will prove far better than anything else that the terrible sacrifices of the last four years have not been in vain. May it be true that not only have we made impossible a recurrence of unprincipled aggression, but that we have also laid the basis for the permanent cooperation of the nations of the world for the benefit of all.

THE PSYCHOLOGY OF DEMOCRACY IN PUBLIC EDUCATION

By DAVID SPENCE HILL
PROFESSOR OF EDUCATION, UNIVERSITY OF ILLINOIS

BUILDINGS, farms, laboratories, machinery, railroads, banks, ships, guns, armies, are necessary although vanishing implements and products of society. The essential and permanent basis of democratic society is that psychic thing called an *ideal.* No present or future exigency should be permitted to separate permanently the idealistic and the practical in an educational system supported by the people—whether the "practical" be of the manual or of the intellectual types of training. This is a good principle to set down at the outset of a discussion of any form of education supported by and for the public. It is peculiarly applicable in the consideration of phases of education called vocational, *i. e.*, education considered as preparation for and participation in occupations of social value. The absolute necessity of conscious ends to be attained by the race, of ideals standardized by altruism, can be appreciated better after a brief consideration of the development and results of knowledge, of power, and of human standards and ideals, from the psychological view point.

Emerging from primitive life, mankind with the slow accumulation of knowledge and skill gained power. With skill and dexterity came dominion over fire, light, the forest, the sea and wild beasts. With the accumulation of fact and knowledge, disease and pestilences were also overcome, pain was diminished by anesthesia, and duration of life prolonged. Especially has trained consciousness vanquished superstitions and fear. However, knowledge and skill brought evils to mankind along with good. There are several kinds of evils and unhappiness that come to the race and to the individual with the evolution of knowledge.[1] *E. g.*: The man of thought foresees the inevitable course of nature in decay and death—and this realization may bring unhappiness in hours of leisure. "La prévoyance, la prévoyance," complains Rousseau, "voilà la veritable source de toutes nos misères." Possibly art and music had one primitive beginning in the reaction from this unhappiness, as well as in the expression of excess, or playful energies. Formal expressions of religion also may have had

[1] Ebbinghaus, "Psychology" (tr. Meyer), 1908, p. 184.

one beginning in the reactions following man's depressing consciousness of his relative minuteness and helplessness in the universe. Still another persistent unhappiness resulting from knowledge, and for which society also has evolved a corresponding antidote, is the misuse of accrued knowledge and skill and power by the more fortunate individuals and groups of men, for the exploitation and even enslavement of their fellows. Thence came slavery, caste, robbery, wars of aggrandizement —with their attendant long trains of evils, such as cruelty, ignorance, poverty, disease, weakness and degeneration. The misuse of knowledge, skill and power through centuries of costly experience has taught mankind that the majority must agree and unite in suppressing evil-doing. Ideals of conduct must be defined and maintained, as well as skill and knowledge. Some of these universalized agreements of society are written visibly in constitutions, statutes, and laws. Other consensuses regarding right conduct are invisible yet potent forces existing in the form of customs, traditions, sentiments and aims and ideals—the last being definite products of creative imagination.

To us in America the word *democracy* is the symbol for all that is best in common agreement, sentiment and determination of a collective people—whether the determination be expressed in book or in conscience. This solidarity of understanding and approval and feeling constitutes the psychic basis of democracy—and is the most real and durable element of the whole structure of democracy. The essential fact stands out clearly that neither knowledge nor skill, or both combined, are sufficient for human welfare, especially in democracy where the good of the people is cherished. Ability to make and enforce law, imagination to create aims and good ideals, and sentiments and emotions that react habitually to the true, beautiful and good—these are quite as essential as accumulation of fact, or of specialized accuracy and speed in coordinated brain, eye and hand. Thus there is a psychological and ethical basis for the development of a true vocational education inculcating a combination of knowledge, of skill and of ideals—an indispensable basis indicated emphatically in the hard experiences of the race. The unimaginable suffering of the World War is a result that accrued where knowledge and skill were unleashed upon the world without controlling aims and ideals truly democratic. The ideals and emotions of the cave man have been linked by Prussian autocracy to modern technic, art and science.

The average man upon occasion is proud, and if necessary is pugnaciously assertive, of his Americanism. Nevertheless it may be difficult for him to define what Americanism means. Elsewhere we have sketched as follows the possible mental content of the average thinking citizen with regard to the matter of those democratic ideals which are the basis of our social life in the United States. Habituated in his every-day thinking there are aspirations, principles and fixed attitudes such as these:

> In the life of the individual there will be liberty compatible with the welfare of the majority of the inhabitants; freedom of personal development and expression will be maintained, but standards of conduct will be established and maintained for the betterment of society. The zealous protection of women and children will always enlist unremitting efforts toward progressive legislation to meet changing social and economic conditions. There is cherished a survival of the nobler sentiments of chivalry as concerns women and children. Equality of opportunity is a right and cooperation of civic responsibility is a duty, in American democracy. Life in its fullness, true liberty and the pursuit of happiness based on health, knowledge and achievement, are as yet found nowhere on this globe, but all these, he knows, surely are nearest of realization in the United States and in Canada, blessed of all countries of a world returned temporarily to fierce struggle for elemental things. In the social consciousness of the seasoned American we can also discern, aside from mawkish sentimentality, a collective, emotional reaction in which are mingled sentiments of admiration for our soil, our mountains, our lakes, our mines and forest—for the very land itself and for the pioneer-conquerors of it, along with convictions held in common concerning the essentials of government and of union, convictions and sentiments that make for determined solidarity and brotherhood—a true patriotism for both peace and war.

If the essence of American democracy is that these habitual sentiments and convictions are nourished in common by the increasing millions of our population, who nevertheless are more and more remote in time from the aggressive spirits who established these principles in this land, then measures can be undertaken by us who now live, for the deliberate strengthening of such habits of mind until they become increasingly permanent. The perpetuity of the elements of our democracy will be uncertain, unless there be effective preparation to train each new generation, and all newcomers, for social participation in the best phases of modern life in America, as well as for industrial efficiency. The best instrument for this undertaking is, we believe, the public educational system, in its manifold aspects from kindergarten through university.

Better realization of the possibilities of democracy in assuring life, liberty, and the pursuit of happiness, and more money

for the public schools, might result from general deliberation upon the basal reasons for the support of education by every unit of our organized people, be it federal, state, county, township, municipality, or other contributory agencies. These reasons may be indicated here by suggesting respectively six principles: (1) Each child is a potential citizen and therefore should be made an intelligent, good man; (2) it is necessary to conserve and increase human power through the acquisition of knowledge and technical skill; (3) the state must supply the child with his biological birthright—a suitable environment for development; (4) the power and money of the whole people are alone adequate for the stupendous task; (5) the years of school life are important aspects or chapters in the book of democracy—rather than mere preparation for its enjoyment. It may be opportune in this connection also to bring in rapid review before the people certain basal facts about the nature of education, its instruments, the difficulties, and the present status of this our greatest American undertaking. One could compile a small volume to include attempts at defining education. We may agree to indicate by the term the "attempt to modify human beings in accordance with chosen ideals and aims." The broadening relations of education emphasize the truth that many elements or factors other than the teacher and the school are operative in modifying the human organism. It is necessary only to hint at the possible effects upon individuals, groups or races, of climate, heat, cold, moisture, dryness, proximity or remoteness from the sea, disease, occupation, the family, the crowd, the church, the press, the theater, peace, war.

So impressive is the magnitude of modern educational machinery that the incessant operation of these other agencies of change in innumerable forms may be overlooked, if we neglect the fundamental characteristics of formal education as an undertaking to modify, alter, to develop, or to suppress, the original inheritances of man's nature. It is true that we may not be able directly to cause or to prevent desired changes in the young generation dwelling daily for some years within the schoolhouse. It is convenient, however, when we define education as a formal process, to say that it is an effort to cause or to prevent modifications in human beings in accordance with a chosen aim or ideal. At best, we can only manipulate stimuli and environment in a manner conducive to the desired changes in the human organism. Education is not properly a daily task for a sleepy pedagogue, a pedant or a mere wage-earner. There

are profound problems in physics, chemistry, zoology, physiology, psychology, hygiene, as well as in ethics, economics, industry and occupations, before the professional educator of tomorrow.

Public education as a deliberate attempt upon the part of the state to mold human beings can have no narrow aim, restricted ideals, or be an exclusive privilege of caste, of sect, of wealth, or of poverty. The process touches all ages of men, both sexes, all races, and is to be articulated with all socially desirable occupations within agriculture, forestry, animal husbandry; industries for the extraction of minerals; the manufacturing and mechanical industries of the factory, building or hand-trades; commerce; public service; professional service; domestic and personal activities; and the merely clerical occupations. Universal education will include eventually in its scope appropriate training in skill, or in knowledge, or in both, of those human beings who exhibit extreme individual variation from their kind, whether the variation be destructive or abnormal, or one of unusual mental capacity, *i. e.*, the supernormal, and also the defective—such as the feeble-minded, the confirmed delinquent; and the blind, and the deaf, and the crippled, whether they be victims of birth, of industrial accident, or of war.

There are to-day kindergartens, primary grades, grammar grades, intermediate schools, junior high schools, classical high schools, commercial high schools, technical high schools, industrial, trade, continuation, part-time and evening schools. Scores of differentiations in school work intended to adapt better the school to individual and community need are familiar to us, *e. g.*, open-air classes, oral teaching of the deaf, classes for epileptics, schools utilizing the preventive mode of attack upon vice and crime. And in addition, utilized by a fractional percentage of our population (less than one per cent.) there are the colleges, the professional schools and the universities. The passage of the Smith-Sears Act of Congress, for the rehabilitation of disabled, returned soldiers, largely through the processes of occupational therapy and of vocational education, is a significant extension in the application of universal education. Whatever may be one's verbal definition of universal education, a glimpse of the above list of typical kinds of educational machinery at work in our country reveals the presence of multitudinous, formal instruments of education which, if well coordinated for the higher purposes of democracy conceived as organized humanism, would constitute a near-realization of universal education in practise.

Classification of Human Types

- **A. As to genesis**
  - *a.* Chromatic race
    - I. White.
    - II. Yellow.
    - III. Red.
    - IV. Brown.
    - V. Black.
  - *b.* Sex
    - I. Male.
    - II. Female.
  - *c.* Nativity
    - I. Native-born
      - 1. Native parentage.
      - 2. Foreign parentage.
    - II. Foreign-born.
- **B. As to personality**
  - *a.* Age
    - I. Minority
      - 1. Infancy.
      - 2. Childhood.
      - 3. Youth.
    - II. Maturity.
    - III. Senescence.
  - *b.* Vitality
    - I. Physically normal
      - 1. High type.
      - 2. Medium type.
      - 3. Low type.
    - II. Physically defective
      - 1. Blind.
      - 2. Deaf.
      - 3. Crippled.
      - 4. Anemic.
      - 5. Tuberculous.
    - Border line types
      - 1. Retarded.
      - 2. Epileptic.
      - 3. Speech defective.
  - *c.* Mentality
    - I. Mentally normal
      - 1. High type.
      - 2. Medium type.
      - 3. Low type.
    - II. Mentally defective
      - 1. Feeble-minded
        - 1. Moron.
        - 2. Imbecile.
        - 3. Idiot.
      - 2. Insane.
  - *d.* Morality and sociality
    - I. The moral (and social)
      - 1. High type.
      - 2. Ordinary type.
    - II. The immoral (and unsocial)
      - 1. Untrustworthy.
      - 2. Incorrigible.
      - 3. Delinquent.
      - 4. Confirmed criminal.
- **C. As to environment**
  - *a.* Home conditions
    - I. Normal
      - 1. High type.
      - 2. Medium type.
      - 3. Low Type.
    - II. Subnormal
      - 1. Neglected.
      - 2. Deserted or homeless.
      - 3. Ill-treated.
      - 4. Orphan or half-orphan.
  - *b.* Literacy
    - I. Literate.
    - II. Illiterate.
  - *c.* Vocational background
    - I. Professional.
    - II. Artisan.
    - III. Unskilled.
    - IV. Idle.
  - *d.* Economic background
    - I. Wealthy.
    - II. Middle class.
    - III. Poor
      - 1. Insolvent.
      - 2. Dependent.
  - *e.* Political background.
  - *f.* Religious background.

Naming solely in general terms the kinds of schools which we have developed in varied forms to meet different needs, is not sufficient to indicate fully the complexity and the magnitude of the task. Within each school, and class, there are differentiated types of groups and of individuals. The skillful adjustment of instruction to individual differences is ever a problem conscious to the intelligent teacher. Even pupils of the same chronological age differ in anatomical and physiological maturity, in mental growth, capacity and interests. Various attempts have been made to exhibit in convenient form an inclusive classification of all the manifold types of human beings which universal education must touch. On p. 448 is one such classification arranged by McDonald[2] upon the threefold bases of genesis, personality and environment of the population groups.

Both the common striving for universal education and also the vigorous expression of individualism are witnessed in the contemporary forms of educational machinery. The present status is not without danger, lest conflict, waste and chaos result from the failure to coordinate into practical administration the whole school machinery of the nation, through the power of broadly democratic and educational ideals, clarified and made controlling in the thinking, customs and laws of our swelling population. Educators have wasted much time in debates about words. The difficulties of some teachers in mental reconstruction, in surrendering prejudices, or, at least, in keeping in proper relation those educational aims or ends which are only immediate or proximate in nature, apart or distinct from those ends, aims and ideals which are consummate or ultimate in nature—are two persistent obstructions to better realization of universal education. Each of the numerous traditional notions defining the "ultimate" aims in education, *e. g., formal or mental discipline, culture, development, perfection, utility, knowledge,* etc., has still its place, and, clarified, doubtless will continue, but they will all be subordinated to a high ultimate aim for public education, an education intended to produce men and women who live in health, in economic productivity, in civic intelligence, and in observance of standards of conduct, and in the happiness of brotherhood, whatever be the occupation or status of the individual. Neither crass materialism, on the one hand, nor obsolete asceticism, on the other, will suffice in place of this unifying conception of the mission of public education.

An individualism bringing personal or national isolation—

[2] McDonald, R. H. F., "Adjustment of School Organization to Various Population Groups," New York, 1915, 145 pp.

in essence selfishness and fear, is as incompatible with American democracy as a radical socialism and collectivism which knows not the individual. In the struggle to define and maintain the sane and righteous balance between the demands of the individual and the demands of the group, comes the trial of democracy. A severe critic of the democracies so labeled in history thinks that popular governments imply a breaking up of political power into morsels, and the giving to each person an infinitesimally small portion. "They (democracies) rest upon universal suffrage, which is the natural basis of tyranny; they are unfavorable to intellectual progress and the advance of scientific truth; they lack stability; and they are governments by the ignorant and unintelligent." Further, declares Maine, "By a wise constitution democracy may be made as calm as the water in a great artificial reservoir; but if there is a weak point anywhere in its structure, the mighty force which it controls will burst through it and spread destruction far and near." Maine's fear of democracy seems based upon the assumption that prejudice and ignorance render the masses more dangerous than the controlling few, because the masses will run counter to scientific conclusions.[3] The agonies of Russia seem to support the theory. This expressed principle, however, only illustrates first, the necessity of universal, public education including inculcation of sentiments of liberty, equality, fraternity, loyalty—the prejudices of democracy, and, secondly, we are reminded that they who control, be they representatives or monarchs, must be animated by democratic ideals in order safely to guide the uses of science at their disposal. The public education we have achieved in America, and the success of our democracy now adequately tested, demonstrates that we are learning how to upbuild and to perpetuate democracy through the instruments of public education, and of ideals made conscious and potent in high places. We have referred to American democracy as symbolizing all that is best in common agreement, sentiment and determination of a collective people who have tested the worth of democracy through the storms of more than a century. This experience, and contemporary world events, increase our confidence in the system and now awaken forethought to safeguard and perpetuate American democracy. First, there has been the matter of overcoming vicious idealism, autocracy, Prussian militarism. which has brought cataclysms. Secondly, there exists also

[3] Garner, J. W., "Introduction to Political Science," New York, 1910, pp. 224, 318–321.

amongst us at home some anarchism, and a pestilential propaganda called socialism. Thirdly, there is the matter of methods and means to be adopted in safeguarding and perpetuating the best of American habits, convictions, sentiments, attitudes and ideals, in the mind of the present and future public.

These mental conditions constitute the foundation rock of our democracy. Our valiant Army and Navy, supported by industry and by our people, united in manifold efforts to "seek the reign of law, based upon the consent of the governed and sustained by the organized opinion of mankind," are the designated agencies to deal directly with the matter of defense and of offense as concerns Prussian autocracy. The public schools are an agency to be relied upon in the matter of perpetuating American ideals. The schools are a tremendous engine for effecting changes in human nature in times both of war and of peace. An idea inculcated firmly in the minds of the Prussian children of twenty or thirty years ago ("With God, for King and Fatherland") and viciously developed to delusions about Kultur finds atrocious expression to-day. In America we are reaping the rich mental and social fruitage of the convictions concerning "Liberty, Equality, Fraternity" inculcated in the minds of our own children born thirty years ago, and of their fathers. Who can calculate, therefore, the glorious results for humanity, in the lives of the unnumbered millions yet to be born, if the schools of to-day effectually inculcate in the creative imagination of children the purest ideals of democracy, ideals refined in the fires of the century and a half of our national existence and in the recent experiences of the world war?

Opportunity exists for those who are expert in the actual technique of instruction to discover and to evaluate for us all available methods of inculcating democratic ideals as consciously selected and followed goals in individual life. It is a phase of the complex problem of moral education, but the undertaking concerns in detail every thing done in the school. Expertness in the technique of teaching, efficient methods, are more urgently needed for this purpose than even in reading, writing and arithmetic—the pedagogue's favorite field for experimentation. Given the content for instruction in ideals of democracy, the problem is to devise methods for making these ideals both conscious and permanently controlling in human lives.

Great has been the demand for technique in imparting elementary knowledge, and the contemporary emphasis upon the vocational aspects of education also calls imperatively upon the

teaching body for economical and effective methods of imparting skills in mechanical occupations. The present national emergency magnifies the two demands for better methods in the acquisition of knowledge and in the acquisition of mechanical skill. An important aspect of each of these two problems—the acquisition of elementary knowledge and of technical skill, is the further introduction of ethical idealism into all teaching, whether it be for knowledge or for skill. It is not our purpose to enter into the detail of this question, "how to teach ideals," the answer to which is being sought ably by such teachers as Bagley, Thorndike, Dewey and Charters. The problem is becoming more difficult now that stress upon vocational education lower than college grade is growing by leaps since the passage of the Smith-Hughes Act. It is recognized that we must have general intelligence, and citizenship, along with technical skill. For example, it is often said that we need sorely the development of industrial intelligence as well as industrial skill. A broad interpretation of *industrial intelligence* reads into this expression (*a*) an *ethical idealism*, as well as (*b*) *information* about industries of economic value to accompany (*c*) *specialized skill* in the sense of manual dexterity and training, coordination of brain, eye and hand. We venture to lay down tentatively the following outline of ten means whereby democracy, including industrial intelligence, may be sought in our schools. In practical contact with individual and with social and occupational groups the wise superintendent and professional educator utilizes many different channels to move forward ethical idealism. A distinction of course fundamental is that between the *lay* (legislative) and the *professional* (executive, supervisory) functions in school administration. The first function belongs to school boards, hence first we speak of the matter of control:

1. *Ultimate, Single Control.*—Systems of public education, whether organized into federal, state, municipal, county or smaller units, should avoid rival boards of control. There should be ultimate, unitary control in order to enforce but one kind of ideals—the ideals of democracy. Our constitution and practises provide safeguards to prevent perversion of unitary control to permanent autocracy. Dual systems of education supported by public funds, whether set up by irreconcilable educational factions, by religious denominations, or by partisan politics, are essentially wasteful, promotive of caste and have not proved satisfactory upon trial. Adherence to *single control*, however, does not negate the value of temporary boards, commissions, or other bodies for educational control,

organized to establish and regulate neglected phases of education in the face of obstructive academic opposition, and constituted with representatives of the schools, of labor, and of capital, and with carefully restricted and defined powers. An approximate example of this type of board, or commission, is the Federal Board for Vocational Education, organized to cooperate vitally with State Boards and with the United States Bureau of Education and other federal bureaus and departments. Both the spirit and the letter of the Smith-Hughes Act make possible a cooperation and unity of effort, rather than rivalry or dualism; ultimate control inheres in appeal to Congress as well as in the legislatures of the States. If the work of the Federal Board later should be absorbed by a national Department of Education, there should be secured a safeguarding of oneness of aim and administration compatible with democracy.

A good type of unitary state control is where the code and the statutes of a state authorize: (1) A small, appointive, or elective-at-large board of education composed of intelligent laymen; (2) these laymen appoint an expert educator to discharge executive and professional functions as head of the state department of education; (3) this executive (commissioner of education) nominates other trained persons to be executives of various divisions of his department—as, division of elementary education, division of high schools, division of vocational education, division of health, division of educational research, etc. The whole school system of the State thus may be coordinated for teaching consistent with democracy. Universities and other special institutions may be included in the scope of such a plan, with necessary boards affiliated with the state board. Municipal and county boards advantageously could be modeled in similar but simpler form.

2. *Didactic Assertion, Simple Teaching of Truths by Word of Mouth and by Printed Page has its Place.*—Reaction from the Socratic doctrine that "virtue can be taught" need not lead us to utter abandonment of the principle that information, understanding, facts, are conducive to steady action. When one considers the universality of imitation in the human mind, and the power of normal suggestion in modifying conduct of individuals and of groups—he is likely to magnify the utility of oral or written words in the inculcation of effective ideals. The "winged word" is the most powerful of all instruments. The difficulty is that our words meant to convey deepest truths often lack the masterly utterance and timeliness of the great teachers—Jesus, Confucius, Socrates, Plato.

3. *Curriculum Changes.*—Educational research has uncovered wasteful practises in tread-mill repetition and inconsistent courses of study in our elementary and secondary schools. Encouraging progress is being made toward economies of time and effort, which will give better opportunity for emphasis upon the civic and ethical bearings of every subject in the curriculum and by every teacher.

4. *Expression or Practice.*—Vivid and incessant oral and visual portrayal of ideals is not enough. There must be expression if the ideals are to be ingrained in individual life. Opportunities for development of expression inhere in the school, in the shop, in play, in social organizations, in participation of pupils in the multiplying activities of the war, such as thrift campaigns, gardening, the Boy Scout movement. The day is past when the teacher of language, or mathematics, or manual training, or science, or history, or civics, or hygiene, etc., may consider safely his subject as of value in itself, and to be taught to receptive or merely absorptive students regardless of any bearings that the subject may have upon active or community life. Every teacher may consciously indoctrinate and make active the principles of democracy as revealed in his subject—be they properly related principles of culture, discipline, utility, knowledge or skill. Only teachers who can do this thing are fully qualified for public education. There are abundant potential avenues in the schools for putting into practise the choicest ideals of equality, fraternity, liberty, fair play, team spirit, manly competition, sympathy, love of our country.

5. *Consciously Developed Attitudes.*—The development of educational psychology has brought forward some facts and methods from general psychology of value to educational practise—as witness the psychology of instincts, of habit, of interest, of attention, of formal discipline, of the learning process, etc., the psychology of the elementary and high-school subjects, and the tendency toward experimentation or trial rather than toward dependence upon debate and oratory in educational advancement. Some new light also has been thrown upon the psychology of prejudices, set convictions, emotional attitudes. Attitudes may be in large measure the product of controllable factors or situations. It would seem that in the matter of inculcating ideals, and those mental complexes called attitudes, which embody both ideas and emotional factors—good opportunity appears for practitioners of applied psychology to tell us more definitely how to develop consciously those desirable attitudes and prejudices toward the good, which may be util-

ized in the development of individual character and for the stability of our democratic society.

6. *Emotionalism.*—Aims and ideals in order to live in daily conduct must be rooted in the impulses, feelings, emotion and sentiments that motivate most lives more deeply than perceptions or reasoning. Cold-blooded analysis of fact, verbal portrayals of truth in immaculate rhetoric, but somewhat totally lacking the qualities of appeal, are not sufficient in teaching ethical and national ideas to pupils. Music, poetry, the drama, real oratory, personal appeal, the Flag, each has a vital function not to be neglected and not to be relied upon as exclusively sufficient.

7. *Specific Education for Patriotism.*—The sentiment of patriotism is a subtle form of emotion. Abiding patriotism as a mental characteristic in the individual includes definite ideas developed by the people of a nation as concerns the common good, equality, liberty and the principles for which our fathers fought. It includes also the affective glow of pleasant feeling which, combined with the ideas about principles, pioneers, country, constitute, altogether, the sentiment of patriotism—a subtle sentiment to analyze, but a real, stupendously powerful, social energy. The point is, there are definite ideas and facts to be nourished in engendering patriotism, ideas found in the Declaration of Independence, in the Constitution, in the non-sectional history of our country, and in the expressions of choice thoughts by our great men.

Teachers who nourish in their hearts true loyalty to American ideals, and who know enough of history, tradition and literature, to supply the indispensable basis of unbiased fact, are the ones qualified to instil patriotism—and no others are. Whether the teacher's subject of instruction be German or science, Latin or gymnastics, English or machine work, the building trades, or home economics—the indispensable qualifications for seasoned loyalty and patriotism are essential in our democracy.

8. *Health.*—"While some gifted persons may possess strong wills in spite of weak bodies, for most people physical and moral vigor are connected intimately," remarks Neuman. Samuel Johnson's remark that the sick man is a scoundrel is given some credence by the numerous instances where vice, intemperance, gross indolence, harmful fears, obsessions, fanaticism and crazed radicalism may be traced to bad health or physical weakness. One of the other functions of public education, in addition to the establishment of standards of individual capacity to share in social life, is to provide the best

conditions for the conservation of physical strength, the prevention of disease and of accident. New significance therefore will attach to the administration of all valid health and safety measures in our effort to conduct a public education conducive to the upbuilding of true democracy. In our pragmatic emphasis upon the spiritual, and upon ethical idealism—we can not afford to ignore the other, the physical aspect of the human organism, whatever may be our metaphysical theory of the nature of the mind-body relation.

9. *Attendance, and Cure of Elimination.*—Our public schools will never serve completely all the people until we achieve: (1) Compulsory and regular attendance during an adequate school-year, and (2) until the present evil of premature elimination is overcome. Schools which in upper grades and in the high schools educate only a small, fortunate fraction of the population are contributing to a caste and aristocratic tendency. That less than a seventh of the pupils who enter the first elementary grade ever graduate at the average American high school is due to various factors in the pupil, in society and in the school, worthy of serious study and determined remedial effort in each community.

10. *Conserve Existing Schools.*—The schools of the past quarter century have succeeded marvelously in preserving the ideals of democracy. Otherwise, how came this unanimity of action, this oneness of purpose and whole-hearted effort of our people working and fighting to preserve the best of civilization and to make the world "safe for democracy"?

An educational pessimist can easily tabulate a score of serious defects in characteristic American public schools—although he might admit relative progress. One weak point revealed by the war has been our industrial unpreparedness, and inability to furnish trained men for and from those industries utilizing skilled labor. At enormous costs these deficits in skill have been met by strenuous emergency measures for training. The world will never be the same again. A twofold problem before us in public education is, first, to supply adequate opportunity for elementary, for liberal and for vocational education in behalf of that ninety-nine and one half per cent. of our population which never enrolls in a college, university or professional school. Secondly, in our effort to reorganize the public educational system thus for democracy, it is essential to conserve and not merely to destroy. Our public school system, with all of its defects, has delivered for world service millions of young men—most of them healthy, efficient, clean-minded, and imbued with the ardor and ideals of democracy.

NERVOUS AND OTHER FORMS OF PROTOPLASMIC TRANSMISSION. I

By Professor RALPH S. LILLIE

CLARK UNIVERSITY

IT is an old story that living protoplasm is "irritable." This is one of the many and undeniably important truths of which—as Dr. Johnson used to say—men need to be reminded rather than informed. The whole living cell or tissue, and in many cases the whole organism, *responds* (as we say) to an environmental change by some characteristic change in its own activity. Such inciting changes or *stimuli* may be of the most varied kind; mechanical influences, changes of temperature, light, chemical substances, the electric current may all call forth in an irritable tissue or organism an active response. The precise nature of this response is determined by the special constitution of the living system, and is largely independent of the character of the stimulus; in whatever way it is stimulated a muscle always contracts, a gland secretes, a protozoon carries out a motor reaction. All this is familiar enough. But what is not always clearly recognized, although evident when we stop to consider, is that when a cell, or a whole organism, responds in this way to a single localized stimulus there is always a *transmission* of physiological influence from the point of stimulation to other regions not immediately affected by the stimulating agent. It is because of the ability to transmit such influence that the living system is enabled to react in a unified manner, *i. e.*, as a *whole*. The active state resulting from the local disturbance seems possessed of an innate tendency to spread and to involve the entire cell, and often to extend to other cells. If we reflect we shall see that this is no merely incidental or occasional vital property, specially developed in certain cells or tissues such as nerve, but that any vital response tends to involve a larger area than the area directly receiving the stimulus; that in fact we are dealing here with one of the most general and distinctive peculiarities of living matter. The continued existence of a living cell, and in a larger sense of each living organism, depends upon its acting as a single self-regulating system, the various separate activities of which mutually influence and control one another and are so coordi-

nated as to secure a definite unity of action in the whole. It is by means of such unified and effectively directed action of the *whole* living system upon its environment that its own survival is made possible; and it is plain that any such unification demands prompt and ready transmission of physiological influence from one region to another.

This may be made clearer by a few examples. In animals we usually find that antagonistic pairs of motor processes, which would interfere with each other if they took place at the same time, are so interconnected functionally that their simultaneous occurrence is impossible. Thus flexor and extensor muscle groups can not normally be innervated simultaneously; activity in the one group of controlling motor neurones automatically prevents or decreases activity in the other; *i. e.*, an inhibitory influence is transmitted between the two regions of the central nervous system which innervate the respective muscle-groups. This reciprocal influence is by no means confined to the nervous system. It is shown, for example, in the passage of peristaltic waves along the intestine, in the locomotor movements of worms, and even in amoeboid movement, and apparently forms an essential factor in all motor coordination. Even the more fundamental physiological processes like growth and metabolism are subject to a similar kind of control; in both animals and plants the growth of one part often inhibits the growth of an adjoining part, and it can be shown that the attainment of the normal form and structure in a developing organism depends largely upon such transmitted influences. What is most remarkable is that they control the rate and character of formative and other processes in spatially separate regions of the organism in a manner which often seems independent of any transfer of material substance between the regions concerned; control by material transfer (hormone influence), which is also widespread, is an entirely different type of phenomenon (apparently sometimes confused with the first). Now coordination of activity, functional, metabolic, and formative, is perhaps the most fundamental characteristic of life-processes in general; it is inherent in all vital organization, which, as I need scarcely remind the reader, includes organization of physiological activity as well as of structure. And since this coordination implies that physiological processes in different regions of the cell or organism mutually influence one another, in a constant and dependable manner, it is evident that transmission is a necessary element in any kind of definite response to stimulation. We can not, after the fashion once pre-

vailing in physiology, speak of "irritability" and "conductivity" as if they were two separate and independent properties of protoplasm. Both are always present. When a cell or a nerve-fiber *responds*, it at the same time *conducts*. If it fails to conduct no response is possible. Accordingly we must conclude that the ability to transmit physiological influence from one region to another is common to all forms of living protoplasm. The readiness, completeness and rapidity of this transmission and its precise functional manifestations vary in different cells and in different organisms, but without it normal vital activity is inconceivable. Conduction, in this general physiological sense, is a universal property of living protoplasm.

The problem of the physico-chemical nature of protoplasmic conduction or transmission is thus one of the most fundamental in biology. It includes such problems as that of the nature of the nerve impulse—one often treated in too special and limited a manner by physiologists—and many other special problems of coordination and integration. It is therefore largely a problem for comparative physiology. What kind of influence is it which is thus transmitted? Since living organisms are systems which operate by means of chemical energy freed by oxidation or other chemical changes in cell-constituents, it is obvious that any influence modifying functional activity must first of all be an influence modifying the rate or character of the chemical processes which underlie and determine the function in question. These chemical processes are collectively termed "metabolism." In any form of protoplasmic transmission, therefore, we have an instance of transmission of metabolic influence to a distance; metabolic processes are primarily affected, and along with these the dependent functional activities of the living system. Our general problem accordingly resolves itself into the problem of the means by which chemical or metabolic influence is transmitted from one region of the living system to another more or less distant region. Such transmission is universal in living protoplasm. The main difficulties of the problem arise from the fact that the process may take place independently of the transfer of material between influenced and influencing regions, and often at a very considerable velocity. These peculiarities are well illustrated by the case of nerve-conduction, which may be regarded as the type-phenomenon of the class. What is the essential physico-chemical basis of this type of transmission?

Now that the fundamental problem has been defined, the situation may perhaps be made clearer by a concrete applica-

tion. Most of us are familiar with the behavior of a typical protozoon like *Paramœcium* and will remember what happens when this organism is locally stimulated, for example at its anterior end. A definite sequence of locomotor processes follows, constituting what Jennings has called a "motor reaction." First of all the ciliary stroke is reversed over the whole surface of the body and the animal backs; then the cilia change their direction of stroke in certain regions, causing a turning movement toward the aboral side; and finally the original ciliary stroke is resumed and the animal again swims forward in a different direction. The slight local stimulus sets up some kind of transmitted influence which modifies in a definite and orderly sequence the activity of the motile surface-structures or cilia in different parts of the body. The resulting changes of movement, which unify and coordinate the behavior of the whole organism in a manner which often appears intelligent or consciously adaptive to our eyes, depends upon the transmission of this influence from the original point of stimulation. The transmitted influence follows a definite path, occupies a definite time in its passage, and calls forth a correspondingly definite succession of physiological events. Since the normal physiological sequence is a constant one, we are justified in inferring the existence of some fixed or stable structural and physiological "organization" in the protoplasm, determining the rate, direction and character of the transmitted influence. At least certain definite conduction-paths must be assumed, forming part of the inherited organization and furnishing a ready-formed basis for the constant sequence of motor activities. Transmitted influences of some kind, coordinated both in space and time, evidently control the whole behavior of the animal, and hence determine the possibility of its continued existence as an organic species. And what is true of a single organism like *Paramœcium* is true of countless others and probably of all. There is infinite diversity of detail in different organisms, in correspondence with the diversity in modes of behavior, but in all cases the characteristic sequences of physiological activity and behavior, on which continued normal life depends, are determined by the definite and regulated transmission of physiological influence between different regions of the organism. In higher animals the chief conducting paths are clearly defined anatomically and constitute the central and peripheral nervous system; but even in the individual cells it is probable that equally definite and delicately coordinated pathways of protoplasmic transmission exist, controlling the local differ-

ences of metabolism and functional activity. The case of protozoa shows that there may be such pathways within the limits of single cells.

Many single cells of higher animals exhibit certain simple types of transmission following local injury, which have only recently been studied in detail and deserve particular attention, since they seem to throw light upon the more complex processes of normal protoplasmic conduction. I refer to the transmission of the effects of local mechanical injury in isolated cells like blood-corpuscles and germ-cells, as shown in the recent experimental work of Kite, Chambers and Oliver, using the methods of microdissection.[1] Any cut or puncture of the cell-surface, if sufficiently extensive, or even in some cases a simple contact of the needle, may result in a progressive and often rapid disintegration of the whole cell. Thus a red corpuscle pricked at one point immediately begins to lose hæmoglobin over its entire surface; a leucocyte similarly treated soon disintegrates. Evidently a change in the protoplasmic surface-film, involving loss of semi-permeability, is transmitted from the point of injury over the whole cell. The cell-surface appears to be so constituted that a rapid local alteration of this kind induces automatically a similar change in adjoining areas. Hence the effect *spreads*. There is an essential resemblance between this kind of transmission and the transmission of the excitation-state in irritable elements. In both cases there is evidence of a transmitted alteration in the osmotic properties of the surface-layer;[2] in the typical irritable element, however, this surface-change is rapidly reversed and the original or "resting" condition is restored, while in the blood-corpuscle the destruction of the surface-layer is permanent and the cell breaks down. It is important to recognize that the transmission of the effects of local alteration is not confined to those specialized cells or cell-structures which we agree to call "irritable"; it is only that in the latter case the transmitted effect is more readily produced, is locally evanescent or reversible, is propagated more rapidly, and calls forth more definite and conspicuous effects than in

[1] Cf. *Science*, 1914, N. S., Vol. 40, pp. 625, 824; Vol. 41, p. 290.

[2] *I. e.*, a temporary increase of surface-permeability appears to be very generally if not universally associated with stimulation in irritable living cells. This change does not remain localized at the point of stimulation, but spreads rapidly and involves the whole irritable element. It will be seen below that a similar kind of self-propagating surface-change takes place under certain conditions in the surface-film formed at the interface between certain metals and the solutions with which they react (*e. g.*, passive iron in nitric acid, mercury in hydrogen peroxide solution, etc.).

other types of cell. In such cases we are accustomed to regard this property as a special physiological function, and call it "conduction." In nerve it is especially highly developed, and for this and other reasons the transmission of the nerve-impulse has often been regarded as constituting a special problem in itself. Nervous conduction, however, is only one special instance of the more general phenomenon of protoplasmic transmission. Yet because of its many striking characteristics, and also because in this tissue the conduction-process is apparently uncomplicated by other processes, most of the special studies of protoplasmic conduction have been made on nerve. I shall therefore refer largely to the results of such studies in considering, as I shall now attempt to do, the physico-chemical nature of the transmitted influence.

What, then, is the essential nature of this influence? It can not depend upon the bodily transport of material between excited and unexcited areas; its rate is far too rapid for that. In man a stimulating influence is transmitted from the central nervous system to the muscles along the motor nerve-axones (each with a sectional area of perhaps 50 to 100 square microns) at a velocity of 120 meters per second; while the most rapidly diffusing dissolved material particles, the hydrogen ions, move at the rate of only a few centimeters per hour, even under the influence of steep electrical gradients. Nor is the influence mechanical in nature, like (for example) the transmission of signals by the old-fashioned wire bell-pulls, for there is no visible mechanical deformation in a nerve or in a *Paramœcium* during transmission. Change of temperature is also ruled out as a possible factor; in a nerve during the passage of a single nerve-impulse the rise of temperature is estimated by Hill as not more than a hundred millionth of a degree; this fact disposes of the analogy to an explosion-wave, a process which is propagated by local rise of temperature associated with increase of pressure. There is also no resemblance to the transmission of physico-chemical germ-effects, as, *e. g.*, in crystallization; in a tube filled with a supersaturated solution of Na_2SO_4 the introduction of a crystal of the salt at one end causes separation of crystals throughout the whole solution, the effect being propagated rapidly from end to end. But in this case a mechanical and optical change and a rise of temperature accompany the process, and neither of these is perceptible in a conducting nerve. Moreover the crystallization process is not spontaneously reversible, and the rapid reversal of the local change is perhaps the most striking feature of nor-

mal nervous conduction. On reviewing the various known modes of transmission in inorganic processes we find none corresponding even remotely to the protoplasmic process, with the possible exception of some form of electrical influence.

But a comparison with the electric current does not seem at first sight to offer any escape from our difficulties. It is true that we have here a case where rapid transmission of chemical influence to any required distance is possible. We may connect a battery by wires to an electrolytic cell at an indefinite distance; when the circuit is closed chemical processes start simultaneously in both battery and cell; and any change in the rate of the chemical process in either system at once causes corresponding changes in the other. This is a simple consequence of Faraday's law of electrolysis. There are, however, at least two essential differences between chemical transmission of this type and nervous transmission. In the electrical circuit the transmission of chemical influence takes place instantaneously, *i. e.*, at the speed of the electric current (3×10^{10} cm. per second), and the intensity of the chemical effect at the terminals decreases as the length of the conducting path increases, because of the inevitable increase in electrical resistance. Further, in such an arrangement there is always a *circuit*, *i. e.*, two spatially separated metallic paths by which the current respectively leaves and returns to the battery; while in the case of a nerve-axone there is only a single slender fiber of high electrical resistance, which conducts chemical influence with apparently undiminishing intensity along its whole length. This last peculiarity should especially be noted; there is no evidence that the nerve-impulse decreases in its intensity as it passes along the normal nerve; on the contrary there is definite and, I think, conclusive evidence that it maintains its local intensity unaltered.

And yet there are many indications that electrical processes play an essential part in protoplasmic conduction; that in fact the transmission of activity from the excited to the adjoining unexcited areas is directly due to electrical influences. The comparison of the nervous impulse to an electric current through a wire is plainly a false one. Nevertheless, the possibility remains that the transmission is the result of electrical effects of a quite different kind. We know that the activity of a living cell, *e. g.*, a muscle cell, is associated with the production of an electric current, the so-called action-current, and that this current is able to stimulate other muscle-cells. Is it not possible that in a similar manner the electrical disturbance

accompanying activity in one region of a muscle-cell or nerve-fiber may arouse activity in the adjacent still unexcited regions of the same cell or fiber? These regions, on thus secondarily becoming active, would influence similarly the adjoining regions beyond, and in this manner the state of excitation might be transmitted as a wave along the irritable element—each successive region activating the one next beyond by means of the action-current at the boundary between resting and active regions. Such an hypothesis would be free from the objections just cited, and in fact it has been suggested from time to time (although usually in a vague and experimentally unsubstantiated form) by various physiologists from Du Bois-Reymond on.

This general hypothesis, that the bioelectric variation itself constitutes the normal exciting condition in the transmission of local activity from place to place in living cells or nerve-fibers, renders intelligible one of the most remarkable and significant general peculiarities of living organisms, namely, their sensitivity to electrical influences. This sensitivity is so great that in Galvani's early electrical investigations the nerves and muscles of frogs were used as delicate electroscopes in studying the effects of friction and similar treatment upon the electrical condition of bodies.[3] And, as all know, the discovery of current-electricity followed from observation of the effects of simultaneous contact of dissimilar metals upon these living tissues. So long as the electric current was regarded as an exclusively artificial or "laboratory" product this highly developed electrical sensitivity of living matter was difficult to understand on teleological or other grounds. It seemed to be a purely incidental peculiarity, probably unconnected with normal function. But we now know that electrical currents are associated with the most various physiological functions, and there is every reason to believe that they are a constant accompaniment of all cell-activities. If this is the case, such currents must constitute a normal feature of the environment of most living cells, at least in multicellular organisms; and that a sensitivity to such currents should exist is no longer surprising. It now seems probable that the bioelectric currents play a general coordinating rôle of the widest possible application in living organisms, and that they form the chief, though not the only, means by which physiological and metabolic influence is transmitted from cell to cell and between different regions of the

[3] A striking instance of extreme sensitivity to weak electric currents has recently been discovered by Parker in the catfish. The simple dipping of a metallic rod into the aquarium produces through local action sufficient current to excit the fish. Cf. *Amer. Journ. Physiol.*, 1917, Vol. 44, p. 405.

same cell. Such a view would regard the phenomena of transmission in cells and nerve-fibers as essentially an expression or consequence of electrical effects resulting from local activity. Let us now inquire if the general peculiarities of the bioelectric variations in such a tissue as nerve—which is the best for illustration because it is primarily conducting in function—are in fact consistent with such an hypothesis.

The transmission of the excitation-state in living tissues must have at least this in common with the other innumerable instances of transmission of physical changes in nature—that the change taking place at one region of the transmitting medium or system in some manner produces or determines a similar change at adjoining regions. By a repetition of this effect the state of activity, whatever its special nature may be, is propagated from region to region. Our present problem is: what is the essential physico-chemical nature of the process which takes place at the excited region of a conducting element (like a nerve-fiber) and causes excitation in adjoining resting regions? We have seen that the electrical variation accompanying activity is the only observable change (in nerve at least) which is known to be capable of stimulating a resting part of the same tissue. We are thus led to form the hypothesis that the bioelectric variation at the active region is the direct cause of stimulation at the adjoining resting region. If this can be shown to be the case, transmission is accounted for, since all portions of the tissue are equally sensitive to electrical stimulation. In his Croonian Lecture, delivered in 1912, Keith Lucas formulates the problem with his customary clearness and exactitude. He reviews the various facts indicating that the bioelectric variation is an inseparable feature of the "propagated disturbance," *i. e.*, of the excitation-wave or nerve-impulse, and proceeds as follows:

> Up to the present the available evidence does not contradict the proposition that the electric response is a constant concomitant of the propagated disturbance. But for the purpose of any hypothesis as to the physico-chemical nature of the latter the mere stringent proof of this proposition would not be enough. The important point for any such hypothesis is whether they are identical, *i. e.*, whether the disturbance of electric potential at one point in a nerve is the actual and direct cause of the same phenomenon in a neighboring part. Any hypothesis must be prepared to state whether the electric phenomena play the essential part in propagation or are to be relegated to the position of a mere by-product.[4]

Evidently this distinction is an important one to bear in mind, for it might well be that the electrical variation accompanying

[4] *Proc. Roy. Soc.*, 1912, Vol. 85, B, p. 507.

the excitation-wave is merely a sign or index of some other underlying process (which determines both the local change and the transmission), and is in itself of no functional importance.

It is necessary first to inquire under what conditions an electric current led into the tissue from outside causes stimulation, and then to inquire whether the current produced by the tissue in its own activity has those characteristics—of intensity, duration, rate of variation, and direction—which will enable it to stimulate the adjoining resting portions of the same tissue. If this is found to be the case, the view that the normal transmission is due to this current will be substantiated; for if the bioelectric current can thus excite the inactive areas, and especially if the rate of this excitation is sufficient to account for the observed velocity of the excitation-wave, there is no reason to seek other causes for the transmission.

In order that an electric current passed through a nerve or other irritable tissue shall cause stimulation, it must have a certain minimal intensity and duration, it must reach that intensity with sufficient rapidity, and it must have a certain direction relatively to the surface of the irritable elements. Too weak a current will not stimulate, nor will one which lasts for too short a time or which rises from zero to its full intensity gradually instead of suddenly. We know, however, from simple observation that in these last respects the current produced by an active muscle or nerve is adequate to stimulate the resting tissue; this is shown by the experiment with the rheoscopic muscle or nerve, in which, *e. g.*, the action current of one muscle is made to stimulate another muscle. The question of the direction of the current relatively to the cell-surface at the region of excitation is more important. In general, electrical stimulation is a *polar* phenomenon; the current stimulates only at the region where the positive stream *leaves* the cell or nerve-fiber; where it enters the cell it causes the reverse effect of inhibition. This is the so-called "law of polar stimulation," which is of very wide if not of universal application in irritable tissues. If the current is led into a nerve by non-polarizable electrodes it can be shown that the excitation-wave arises at the negative electrode or cathode; if the positive electrode is interposed between the cathode and the muscle the excitation-wave may fail to reach the latter because of the inhibitory or "blocking" influence at the anodal region of the nerve. Similar facts apply to muscle; here also where the positive stream leaves the tissue it excites, and where it enters it inhibits. The physiolog-

ical effects produced by breaking the current illustrate the same law, since in this case the reverse polarization-current is to be regarded as the cause of stimulation.

Now when we study the peculiarities of the bioelectric current produced by the conducting tissue in its own activity we are at once struck with the fact that this current has all of those characteristics of intensity, duration, rate of change and direction which would be required if the current were actually *designed* to stimulate the tissue at the adjacent resting regions and bring it again to rest at the active region. All of the conditions required for the automatic transmission of the excitation-state from active to resting regions are in fact present. This may be seen from a consideration of the diagram (Fig. 1).

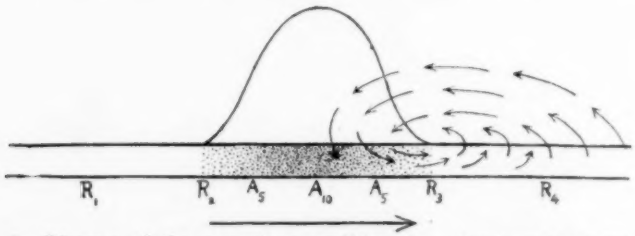


FIG. 1. Diagram of the momentary conditions in a frog's motor nerve at 20°. The shaded region marked A, between R_2 and R_3, is occupied at the instant under consideration by the excitation-wave, which is regarded as advancing in the direction of the large arrow at the rate of 30 meters per second. Its length, assuming the total duration of the local process (as indicated by the duration of the local bioelectric variation) to be .002 second, is 6 cm. The excitation-process is just beginning at R_3, has reached its maximum at A_{10}, and has just subsided at R_2. The curve represents the variation from the resting potential at different points in the active region; the maximum P.D., at A_{10}, is ca. 40 millivolts. The regions marked R are in the resting state. The small arrows indicate the direction of the bioelectric current (positive stream) in a portion of the active-resting circuit. Between R_3 and R_4 its intensity is sufficient to excite the nerve; excitation is thus always being initiated at a distance 3 cm. in advance of the wave-front (*i. e.*, up to R_4). For a somewhat similar distance R_1R_2 in the wake of the excitation-wave the nerve is refractory to stimulation.

The region which is in a state of activity is electrically negative to the regions which are in a state of rest; *i. e.*, there is a circuit in which the positive stream flows in the external medium from inactive to active regions; the current enters the cell-surface at the active region and leaves it at the inactive regions. An external current from a battery having this direction would tend to excite the tissue at R and tend to inhibit an already existing excitation at A (see Fig. 2). There is no apparent reason why a self-generated current should have different physiological effects from one which reaches the tissue from an outside source. Hence we are forced to conclude that the local bioelectric current, as soon as it originates, tends to excite

or activate the resting regions immediately adjoining the active area, and to cut short or inhibit activity in the active area itself. We may compare the active and the adjacent inactive areas with a pair of electrodes applied to the surface of the tissue, with the obvious difference that these areas are continually changing position, keeping pace with the excitation-wave as it advances. The consequence of this is that as each successive

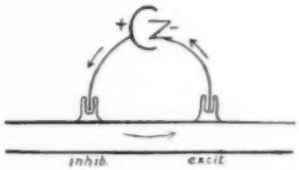


FIG. 2 (inserted for comparison) indicates the effects of passing an external current through a nerve from a battery by non-polarisable electrodes. At the entrance of the current (region corresponding to *A* in Fig. 1) the effect is inhibitory; at its exit (corresponding to *R*) excitatory.

region becomes active, excitation is automatically induced at adjoining regions, and automatically cut short at the active region itself. What we actually observe, quite apart from hypothesis, is that a wave of activity, accompanied by a local electrical circuit, travels in either direction from the original point of excitation. Since this electrical circuit is an essential component of the activation-wave, it is not surprising that the latter produces the characteristic physiological effects of an electric current—excitation at one pole, inhibition at the other —at every region which it traverses in its course. Both the self-propagating and the self-limiting character of the local excitation-process may thus be understood. It should again be noted that excitation at one region, in constant association with simultaneous inhibition at another, is a frequent phenomenon in living organisms, not only in the central nervous system, where it is well-known under Sherrington's term of reciprocal inhibition, but also in locally controlled muscular movements like peristalsis (myenteric law), and even in growth processes and amœboid movement. The condition observed during the passage of the excitation-wave along a nerve-fiber, where the region *in advance* of the wave-front and that immediately *behind* are oppositely affected, being respectively stimulated and inhibited, is thus in no sense unique or unexampled. A fundamental property of protoplasm, that of being influenced in a polar manner by the electrical current, is apparently the essential factor in all of these phenomena.

Why the excitation-wave continues its progress in the one

direction, and does not strike back, so to speak, may seem to require explanation. Why should not any region of the tissue, when it has once returned to rest, be again excited by the active area which is receding from it, just as it was previously excited by the active area advancing toward it? This effect, however, is rendered impossible by the fact that the tissue always becomes temporarily inexcitable for a brief period (the so-called refractory period) immediately following excitation. The excitation-wave thus leaves behind itself a trail or wake of inexcitable tissue, and by the time any single local region has recovered its normal excitability the region of activity is already at too great a distance in advance to exert any stimulating influence at the recovered region.

It would thus seem that when we take into consideration the fact of an electrical circuit between active and inactive areas, and apply the law of polar stimulation, the wave-like transmission of the active state along the nerve-fiber may be accounted for, if we assume that the intensity of the bioelectric current traversing the resting region at a certain distance in advance of the active region is sufficient for stimulation, and that its duration and time of development at that point meet the chronological requirements of the tissue. It can, however, be shown that this is almost certainly the case. The potential-difference between excited and unexcited areas can be measured, and in a frog's nerve has a value of 30 or 40 millivolts; two platinum electrodes with the same P.D., placed 3 or 4 centimeters part in contact with the nerve, will give a current sufficiently intense for excitation. The normal bioelectric current passing between an active region and an inactive region at a similar distance apart (say 3 cm.) should have the same stimulating efficacy as that between the platinum electrodes, since the P.D. and the conditions of resistance are similar in the two circuits; and there are other facts indicating that the current of the local bioelectric circuit has a sufficient intensity at a distance of two or three centimeters from the active area to stimulate the resting tissue. We know too the duration of the local current and its rate of development; these may be ascertained by measuring the time-relations of the bioelectric variation with the string galvanometer. By this means the local variation of potential at the excited area is shown to occupy a certain time which in a given tissue is definite and characteristic,—*e. g.*, in frog's motor nerve, ca. .002 seç. at 20°, according to Garten's observations;[5] *i. e.*, the variation rises from zero to its maximum and

[5] *Cf. Garten*, Winterstein's "Handbuch der vergleichenden Physiologie," 1910, Vol. 3, Part 2, pp. 135 seq.

subsides at a definite and rapid rate. Lucas and Lapicque have shown for a large variety of tissues from different animals that the normal duration of the bioelectric current and its normal rate of change are closely similar to the duration and rate of change required in the minimal electric current which excites the tissue on being led into it from outside. The tissue is *timed*, as it were, to be excited by a current of a definite duration and rate of change which are essentially the same as those of the current produced by the tissue itself in its own activity. Speaking teleologically, we might say that each tissue is *adapted* to respond to its own action current. It is evident that the rate and degree of the change of potential at the active area will determine the rate of variation and the intensity of the current traversing the unexcited region of the tissue at any fixed distance from that area (see diagram, Fig. 1). The intensity of the portion of current which thus traverses the surface of the nerve-axone at any point will of course depend upon the P.D. and the total electrical resistance of the circuit which includes that point (Ohm's law), and hence will be greater in the immediate neighborhood of the active area than farther away. This implies, however, that there will be a certain minimal distance from the active region at and beyond which the current traversing the resting tissue will be too weak to excite. At all points nearer than this critical distance (R_1 in the diagram) there will be excitation. In frog's nerve, as already pointed out, this distance is probably about three centimeters under normal conditions, but it is no doubt subject to considerable variation. The more sensitive the tissue is to weak electric currents the greater this distance will be, and hence the more rapid the rate of transmission. This is probably the chief reason why, in general, highly sensitive tissues conduct rapidly.

We may thus form the following picture of the transmission-process in such a tissue as nerve. At a certain time-interval after the local stimulation the resulting local bioelectric current will cause excitation in the adjoining resting regions of the tissue at all points up to a certain maximal distance beyond the original site of stimulation. These regions on becoming active will at once repeat this effect on regions beyond, and if the excitation-process does not lose in its intensity as it advances along the tissue it is clear that by continued repetition of the same process transmission to any distance is possible. Under such conditions there would be no possibility of the excitation-wave dying out before it reached the end of the tissue, any more than in the case of an ignition-wave in a train of gunpowder. In

both of these instances the energy required for both the local process and the transmission is furnished by the local chemical change; as the wave of chemical activity passes from point to point there is no necessary decrease in the energy available for the local process,—*i. e.*, nothing comparable to the inertia of a moving body, tending to bring the process eventually to a rest. We have, in fact, direct evidence that just such conditions exist in the normal nerve-fiber. The work of Gotch, Lucas and Adrian, and others has shown that in a normal nerve the least stimulus capable of causing excitation produces a response of full intensity; in other words, that the "all-or-none" principle applies to the nerve-fiber as well as to the normal unfatigued voluntary muscle-cell or to cardiac muscle.[6] Hence at the point R_1 in the diagram, *i. e.*, at the maximal distance in advance of the excitation-wave where the intensity of the local bioelectric current is sufficient for excitation, a full response is elicited; and by continual repetition of this effect the wave travels uninterruptedly along the tissue independently of its distance from the original point of stimulation.

The above account of the conditions of protoplasmic transmission is not so much hypothesis as it is reconstruction of the whole process on the basis of well-established single facts of observation and experiment. But can this conception account for the varying speed at which the excitation-wave travels in different tissues, and especially for the high velocity (120 meters per second) which it attains in the motor nerves of mammals? We can answer this question by considering the rate at which the local excitation-process develops. We have a measure of this rate in the time occupied by the bioelectric variation. It is clear from the diagram that if the local change of potential at any region is quick and prompt the transmission to adjoining regions will be correspondingly rapid, while if it is slow the transmission will also be slow. This is inevitable if the local excitation is directly due to the local current formed between active and inactive regions. A quick rise of this current from zero to its maximum will thus mean quick transmission. And in fact comparative observations show that a close relation exists between the rate at which the local change of potential rises to its maximum and the rate at which the excitation-wave is propagated. In frog's nerve at 18° the upstroke of the action-current curve occupies ca. .001 second; to this corresponds a propagation-velocity of ca. 30 meters per second;

[6] Cf. Keith Lucas, "Conduction of the Nervous Impulse," London, 1917, for data and references.

at 32° the corresponding time is approximately halved, ca. .0005 second, and the rate of transmission is doubled. Now if we assume that the current of the bioelectric circuit, as soon as it attains its full intensity, stimulates the resting region at all points up to a distance three centimeters in advance of the region which is already active, we see that at .001 second (at 20°) after excitation has begun at one point it is initiated at a point 3 centimeters in advance of that point.[6a] This means a transmission-velocity of 30 meters per second. And at a temperature 20° higher, with a temperature-coefficient (Q_{10}) of 2, the rate would be 120 meters per second. Lucas has shown in experiments on the sartorius muscle of the frog that rise of temperature increases the rate of the local variation of potential in almost exactly the same proportion as it increases the rate of transmission.[7] And in those numerous tissues where the bioelectric variation is slow, the propagation-rate is also slow, as in the non-medullated nerves or the heart-muscle of vertebrates, or the nerves and muscles of many invertebrates. There seems to be no question that the speed of the local variation of potential is the chief factor determining the speed of propagation. It must be understood, however, that other factors play a part and that the proportionality may not be exact, although in the same tissue, as Lucas' work has shown, the parallelism is very close.[8]

Some curious consequences follow from this correlation between the time-relations of the local electric change and the speed of propagation. Since the stimulation of any resting region by the active region adjoining is due to the electric circuit between the two regions, it is essential that the time-factors of excitation should be similar in the two. This is of course normally the case in any single conducting tissue like a nerve, since all regions of the tissue have similar properties. We should expect that the same rule would also apply in the transmission of excitation from one tissue to another, if this kind of transmission is similarly determined; and as a matter of fact comparative observations show that rapidly responding muscles are always innervated by rapidly responding nerves, and vice versa.

[6a] It must be remembered that the transmission of electric influence from region to region in a circuit is instantaneous (*i. e.*, 3×10^{10} cm./sec.) whether the conductor is metallic or electrolytic.

[7] K. Lucas, "On the Relation between the Electric Disturbance in Muscle and the Propagation of the Excited State," *Journal of Physiology*, 1909, Vol. 39, p. 207.

[8] In *Amer. Journ. Physiol.*, 1914, Vol. 34, pp. 417–420, I have given a table showing the relation between the local rate of development of the bioelectric variation and the speed of propagation of the excitation-wave.

Lapicque has shown that there is a general correspondence between the rate of the bioelectric variation in a nerve and that in the muscle which it innervates.[9] A muscle with a rapid time-factor of excitation—which means a rapid electric variation—contracts rapidly, *i. e.*, has a short single twitch; and a nerve with a rapid time-factor conducts rapidly. Hence quickly contracting muscles are always found to be innervated by quickly conducting nerves,—a relation which Carlson observed years ago,[10] but which has become intelligible only with the development of our modern views of excitation. This relation is simply an incidental consequence of the fact that the electric variation, if it is to stimulate a tissue, must vary at a certain minimal rate which is determined by the nature of the tissue. As Lapicque puts it, the muscle and its innervating nerve are "isochronous," *i. e.*, have similar time-factors of excitation; if this isochrony is disturbed, as, *e. g.*, in poisoning by curare which slows the excitation-process in muscle, transmission is no longer possible. Accordingly it appears that for transmission from one irritable element to another the time-factors of their respective excitation-processes must coincide, or at least not diverge too widely. Certain other peculiarities of conduction from element to element, such as the irreciprocality of conduction between the neurones in the central nervous system, may perhaps also be explained on the basis of this general principle.[11]

Another consequence of the present theory of protoplasmic transmission is that under otherwise similar conditions the rate of transmission will be a direct function of the electrical conductivity of the medium. The bioelectric circuit through tissue and medium has naturally a certain ohmic resistance, which is mainly determined (apart from structural conditions) by the nature and concentration of the electrolytes present, since all living tissues are electrolytic conductors. The intensity of the current in the bioelectric circuit at any point (*e. g.*, R_1) a certain distance in advance of the active region will thus be determined by the electrical conductivity of the portion of the circuit which includes that point. Hence a decrease in electrical conductivity should decrease the maximal distance between active and responding regions, *i. e.*, should decrease the rate

[9] Cf. Lapicque, *Comptes Rendus Soc. Biol.*, 1907, Vol. 13, p. 787, and 1908, Vol. 15, p. 733.

[10] A. J. Carlson, *Amer. Journ. Physiol.*, 1904, Vol. 10, p. 401, and 1906, Vol. 15, p. 136.

[11] Cf. my paper cited above, p. 424; also *Science*, N. S., 1918, Vol. 48, p. 58.

of the transmission along the conducting element. In the recent work of Mayer on the propagation-velocity of the nerve-impulse of the medusa *Cassiopea* in sea-water of varying dilutions, a remarkably close parallelism between the electrical conductivity of the medium and the speed of the impulse has in fact been found.[12] If, for example, the electrical conductivity is decreased by a third the rate of transmission is found to be lowered to about the same degree. And in work which Mr. Pond has recently carried out in the Clark laboratory, on the transmission of the contraction-wave in strips of heart-muscle, it was found that dilution of Ringer's solution with isotonic sugar solution causes a definite decrease in the speed of the wave, and that the original speed tends to return if the tissue is replaced in the undiluted salt solution. The relation between electrical conductivity and rate of transmission is not so direct in this case as in Mayer's experiments with *Cassiopea*, but this is hardly to be expected in view of the nature of the tissue and the number of variables involved. It must be remembered that changing the nature of the medium inevitably affects the physiological state of the tissue itself. Mayer finds that it is only if the sea-water is diluted with distilled water, within a certain limited range of dilutions, that electrical conductivity and propagation-velocity vary in a parallel manner. If these limits are exceeded, or if the medium is concentrated instead of diluted, the parallelism fails. If the sea-water is diluted with isotonic $MgCl_2$ solution instead of water, the speed is reduced to about the same degree as if water is used, although electrical conductivity is little changed. In this case the specific depressant influence of magnesium enters as a factor. And change of temperature has a much greater influence on the velocity of propagation than on electrical conductivity. But it is probable that such facts simply obscure without altering the essential dependence of the transmission-rate on electrical conductivity. The latter is only one out of a great variety of factors, some of which are metabolic in nature. If, while keeping temperature constant, we could change the electrical conductivity of the tissue-medium without essentially altering the normal properties of the tissue, the propagation-rate, according to the present theory, should exhibit a close dependence on electrical conductivity. These conditions seem to be approximated in *Cassiopea* when the sea-water is diluted within moderate limits. It is probably because of the remarkable resistance of the *Cassiopea*

[12] A. G. Mayer, *Amer. Journ. Physiol.*, 1917, Vol. 42, p. 469, and 1917, Vol. 44, p. 591.

tissue to injurious influences, including changes in the osmotic pressure of the medium, that the curve of propagation-rate in dilute sea-water follows so closely the curve of electrical conductivity. These results throw an interesting light upon the general physiological significance of the salts always present in living tissues and their surrounding media. Both protoplasm and medium must possess a certain electrical conductivity if the transmission of physiological influence by bioelectric circuits is to be possible. And the inorganic salts of protoplasm may be important largely because they impart this necessary conductivity. We need not assume that this is the only or even the chief rôle of the salts, but it is undoubtedly an essential one.[13]

We have now briefly reviewed the chief characteristics of the conduction-process in living tissues and have come to the conclusion that its physico-chemical basis is essentially a simple one, depending upon the formation of local electrical circuits between the active and the adjoining inactive areas of the tissue. With elements which are sensitive to electrical excitation, and also give rise to electric currents in their own activity, such transmission of excitation is inevitable. If, however, the essential conditions are actually as simple as this, we ought to be able to produce phenomena of the same kind in non-living inorganic systems. There is no apparent reason why this type of transmission-process should be confined to living matter. General evolutionary considerations naturally lead us to this conclusion, since the living has developed from the non-living. We are thus led to inquire if there are in fact any known inorganic processes where transmission of chemical influence takes place under conditions similar to those which we have just described.

(To be concluded)

[13] The fact that stretching a nerve (within moderate limits, so as not to injure the tissue) leaves its rate of conductivity essentially unaltered is in harmony with the present theory. Evidently some condition which varies directly with *distance, as such*, determines the rate of transmission. This experiment indicates that the interval traversed by the excitation-wave in unit time is not that between two *structurally* defined points of the nerve, but is determined by the length of the column of fluid (*i. e.*, electrolytic solution) between the active and the responding areas (corresponding to the interval between R_2 and R_1 in the diagram). The observed electrical conductivity of any solution is directly proportional to the distance between the electrodes. Cf. Carlson, "Evidence of the Fluidity of the Conducting Substance in Nerve," *Amer. Journ. Physiol.*, 1905, Vol. 13, p. 351, and *ibid.*, 1911, Vol. 27, p. 323; also McClendon, *Proc. Nat. Acad. Sci.*, 1917, Vol. 3, p. 703.

THE PROGRESS OF SCIENCE

EDUCATION FOR AMERICAN SOLDIERS IN FRANCE

THE University at Beaune, twenty miles south Dijon, is now in full operation, according to letters received by Secretary Stokes of Yale University, chairman of the committee which during the past year has represented the Army Educational Commission in this country. Over six thousand students from the army were registered by the middle of March, these being divided into the following colleges—Colleges of agriculture, arts, business, education, engineering, industry and trades, journalism, law, letters, medical sciences, music and science. The teaching faculty includes over 500 men drawn from the army and from the experts—several hundred in number—sent over by the Young Men's Christian Association for developing the plans of the Army Educational Commission.

The organization of the university includes a superintendent, Colonel Reeves, formerly president of Norwich University, Vermont; an educational director, Professor Erskine of Columbia University, chairman of the Army Educational Commission; the directors of the various schools; the faculty, etc. Each term is for three months, the first term being March, April and May; the second, June, July and August. Each student carries as a minimum three lectures or recitation hours daily during five days of the week, and four and a half hours daily in study periods.

In addition to the University at Beaune, the army educational commission has arranged for students to attend British and French universities. A recent cable from London reports the enrollment of American soldiers on detached service in British universities as follows: Oxford 200, Cambridge 205, London 725, Edinburgh 215, Glasgow 265, Sheffield 20, Bristol 21, Birmingham 75, Manchester 75. In France there are 2,000 students at the Sorbonne in Paris alone. Of these 400 are in law, 650 in letters, 798 in science and 150 in medicine. The number at the Sorbonne is so great that it has been necessary to appoint a special American reference librarian, Captain A. Law Vogue, of the Engineering Corps, former reference librarian of the Mechanics Institute in San Francisco. About 2,000 American students are at the other French universities including a large number at Bordeaux, Toulouse and Grenoble. At each of these universities there is an American army officer in charge and a representative of the army educational commission as a dean of students. No student is detailed to a French university unless he has had at least two years' work at an American college, and agrees to remain to complete the three months term. The officers and professors of the French universities have done everything in their power to facilitate the studies of American students.

Special emphasis is being placed on agricultural education, an army farm school having been opened at Allerey in April. It is under the supervision of President Butterfield, of the Massachusetts Agricultural College, a member of the army educational commission. It takes care of students who are not sufficiently advanced to pursue agricultural courses at the university in Beaune. Over 1,000 are in attendance and about 350 acres of land are available for farm demonstration work.

Design for the Eastern Facade of the American Museum of Natural History.

In addition to these facilities, agricultural "institutes" covering three days are being held at various places.

Another development is that of the correspondence college. The subjects in which students may take correspondence work are as follows: Civics and citizenship, salesmanship and personal development, gasoline and automobile, farm management, arithmetic, geometry, history of the United States, shorthand, algebra, trigonometry, shop arithmetic, advanced shop mathematics, steam boilers, heat and steam engines.

In addition to these opportunities, there is, as already announced, a system of post schools in the army which has been developed by Mr. Frank Spaulding, superintendent of public schools of Cleveland, Ohio, who with Professor Erskine and President Butterfield make up the army educational commission sent over by the Young Men's Christian Association. These give instruction in common school subjects and lead up to divisional high schools where the instruction is midway in grade between that of the post schools and of the university.

Running through the whole educational plan abroad is the emphasis on citizenship. Not only is instruction in this subject emphasized at the various schools, but "institutes" are held at various places for intensive instruction. The first of these began in Verdun on March 26. The troops were brought in by their commanding officers in groups from 200 to 500; speakers presented problems of public health, community betterment, economic relations, etc. Exhibits and motion pictures were used to enforce the lessons. Emphasis is also being placed on vocational guidance. A group of experts is stationed at Le Mans, where most of the troops are quartered for several weeks before sailing home. Here everything possible is done to supply soldiers with information regarding the industrial situation in America, and to give the men personal advice as to trades and occupations.

THE AMERICAN MUSEUM OF NATURAL HISTORY IN 1918

THE American Museum of Natural History in New York City completes this year its semi-centenary, but the celebration of the anniversary has been postponed owing to war conditions. During this period the city has contributed $5,318,820 for building purposes and somewhat over four million dollars for maintenance, while the trustees have presented to the city collections and endowments valued at nearly fifteen million dollars. It is now twelve years since any addition has been made to the buildings. The museum has an ample site for extension, and as shown in the accompanying illustration plans have been drawn for a facade facing Central Park. It is, however, to be feared that under existing conditions the city is not likely to make appropriations for new buildings, desirable as it would be to celebrate in this way the fiftieth anniversary of the foundation of the museum.

For the current year, in fact, the city has decreased its appropriation for maintenance by $25,000, the decrease being in effect $50,000 because of mandatory increases in the wages of employees who have been earning $1,800 and under per year. In 1918, the trustees contributed the sum of $88,348 for the payment of salaries and other maintenance expenses for which the city budget had not made sufficient provision. This year, with living expenses no lower, and a maintenance fund smaller, it has not only been found impossible to make deserved salary increases, but a number of employees have been dismissed. Further plans for retrenchment include

SIR WILLIAM CROOKES.

The eminent chemist and physicist, whose death at the age of eighty-six years, removes one of the last survivors of the great group of scientific men who gave the Victorian Era its distinction in science.

closing one half the exhibition halls, keeping the museum open only during daylight hours, cancelling all evening lectures, discontinuing circulation of teaching nature study collections to the public schools of the city, except in the Borough of Manhattan, reducing from twenty-four to ten the number of lectures given at the museum to public school children, and discontinuing all lectures given in the schools.

The museum, during 1918, turned its greatest effort to war work, and, owing to the number and variety of specialists in its many departments, was able to render a very real and valuable service to the United States and to the allied nations. The various preparedness and food utilization and conservation exhibits drew crowds of people eager to see how they could safeguard and improve their health, and how to obtain the most nourishing and attractive food at the lowest cost.

In exploration and field work during the past year but little activity has been possible. Practically no new work has been undertaken, the museum limiting itself to carrying on in so far as possible projects which were already under way. The second Asiatic zoological expedition, under the direction of Mr. Roy C. Andrews, has been able to secure a number of large game animals from China. The third Asiatic zoological expedition, conducted by Mr. Paul J. Rainey, assisted by Mr. Edmund Heller, collected in adjoining regions. This work was financed entirely by Mr. Rainey. Work in South American archeology and ornithology has been done by Dr. Herbert J. Spinden, Mr. George K. Cherrie and Dr. Frank M. Chapman, who has combined the advancement of museum interests with Red Cross activities. The collecting of fossil vertebrates, long under way, has been continued during the past year by Mr. Barnum Brown, in Cuba, Mr. Walter Granger, in Colorado, and Mr. Albert Thomson, in Nebraska. Investigations into American Indian life and archeology were continued by Dr. Clark Wissler in Ohio, Messrs. Earl H. Morris and B. T. B. Hyde in New Mexico and Mr. Leslie Spier in Arizona. Mr. Roy W. Miner has carried on his researches in invertebrate zoology at Woods Hole, Mass.

It has been possible during 1918 to complete a number of new habitat groups, many of which were already under way in 1917. These include the Florida Group—the largest and finest the museum has so far produced. It represents a typical Florida cypress swamp teeming with various forms of life, and presenting much information to even the most casual observer. Another fine group in the 1918 series is the Nahant Tide Pool Group, which reproduces the "Agassiz cave" of Nahant. The other groups, which are less elaborate, are the Blue Shark, Lemur and Migratory Butterfly Groups. A special exhibit of teeth, illustrating the kind, method of growth and replacement, etc., of the various types of mammal teeth, was also installed. Two notable single specimens were prepared and placed on exhibition—a mounted specimen of an okapi—a rare and shy animal of the African interior—and a model of a giant magnolia (*Magnolia macrophylla*), which is so life-like that visitors invariably mistake it for the actual flower, wonderfully preserved. The year also saw the practical completion of the rearrangement of the hall of primates.

EXPLORATION IN THE AMERICAN ARCTIC REGIONS

UNTIL recently only the larger features of the northern part of the American Arctic region have been known. The coast of this region has now been explored for more than

500 miles westward from Herschel Island to Point Barrow, and in all this distance, except at these two places, practically no permanent human habitation can be found. The sea is visited only by an occasional whaler or by a United States revenue cutter, and the land back from the shore tempts few to its wastes except geographers or geologists, who will not be content until they have explored and mapped all parts of the world. The results of long-continued travel and study in this far-off land by one of these explorers, Ernest deK. Leffingwell, have recently been published by the United States Geological Survey, Department of the Interior, in a report entitled "The Canning River Region, Northern Alaska."

Mr. Leffingwell spent nine summers and six winters on the Arctic Coast, made thirty-one trips, covering about 4,500 miles, by sled and small boat, and traversed the coast ten times by ship. Nearly all other parties that have made explorations in Alaska have been large enough to permit a division of the scientific observations and the physical labor incident to travel among several men, but during most of the time he devoted to these explorations Mr. Leffingwell had only one white man to help him—a man who could take no part in the scientific observations. In many of his journeys he had only one or two Eskimo companions, and in some he traveled entirely alone. He chose his own field and made explorations at his own initiative and expense, and the results he sets forth in the report just published are therefore in every sense of the word entirely his own contribution to science and to a better understanding of Arctic Alaska.

The Canning River region, which is the principal subject of the report, lies one third of the distance between the international boundary and Point Barrow. It is about midway between the area explored in 1911 and 1912 by the International Boundary Survey party, to which A. G. Maddren, of the United States Geological Survey, was attached as geologist, and the Colville River region, which was mapped both topographically and geologically in 1901 by a party sent out by the United States Geological Survey in charge of W. J. Peters and F. C. Schrader.

The southern part of the Canning River region lies in the Endicott Mountains, whose high, rugged, snow-clad peaks rise to elevations of 9,000 feet. Many large streams head in these mountains and flow northward, transverse to the trend of lower ridges, which extend east and west. At a distance of fifteen to fifty miles south of the coast these ridges disappear and the country has a gently sloping, almost unbroken, surface. This shoreward region is simply a flat tundra plain dotted with shallow ponds and lakes. Many of the larger rivers flow through this plain in cuts so shallow that their existence might not be suspected at a distance of half a mile.

SCIENTIFIC ITEMS

WE record with regret the death of Frederick Du Cane Godman, the distinguished English naturalist, and of J. J. T. Schloesing, professor of agricultural chemistry at Paris, who has died at the age of ninety-four years.

THE British Association for the Advancement of Science will resume its series of annual meetings this year at Bournemouth from September 9 to 13, under the presidency of the Hon. Sir Charles Parsons.—The annual meeting of the National Academy of Sciences was held at the Smithsonian Institution in Washington at the end of April. The William Ellery Hale Lecture was given by James Henry Breasted, professor of Egyptology and oriental history, University of Chicago, on "The Origin of Civilization."